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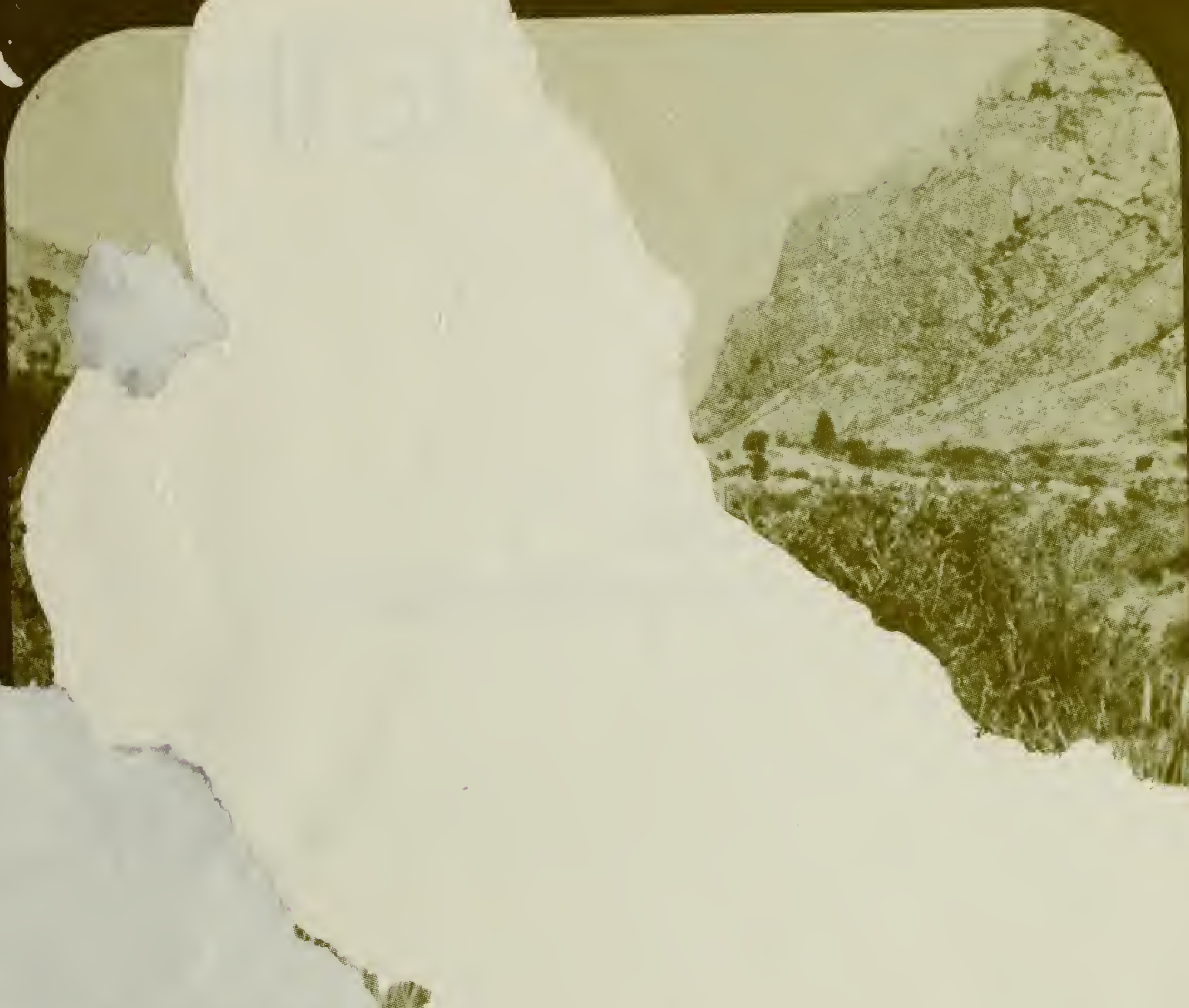

The Impact of Human Use Upon the

CHISOS BASIN

and Adjacent Lands

PAUL D. WHITSON
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Preface

The purpose of this study was to evaluate the following aspects of the Chisos Basin and adjacent lands:

1. The distribution and composition of the vegetation as it presently exists.
2 The impact, present and future, upon natural conditions of camping, roads, other cultural developments, use by horses, and other human activities.
3. The distribution and composition of the vegetation as it might exist today if it was not affected by European man.
4. The nature and distribution of the soils of the area.
5. The consequences of any significant climatic changes in the area, based upon information.
6. The detrimental effects, if any, to the natural vegetation below Oak Springs and Cattail Falls because of their use as the primary water supply sources for the Chisos Basin physical development.

In addition to the evaluations of the above, recommendations will be made for management of the area to reduce or avoid unnatural changes associated with present and proposed human use. Recommendations for the rehabilitation of those areas already seriously altered by human use will also be included.

The Chisos Basin, as defined in this book, is the natural bowl bounded by Pulliam Ridge on the north, Casa Grande and Roger Toll on the east, Emory Mountain on the south, and Ward Mountain and Vernon Bailey on the west (Fig. 1). Between the latter two is the Window through which Oak Creek spills into Oak Creek Canyon below. To the south of Oak Creek Canyon is Cattail Falls, the major drainage site of the upper Ward Mountain. The Chisos Basin encompasses roughly 6 $miles^2$ of steep, rocky terrain and ranges in elevation from 4300 ft at the Window Pouroff to 7835 ft on Emory Peak.

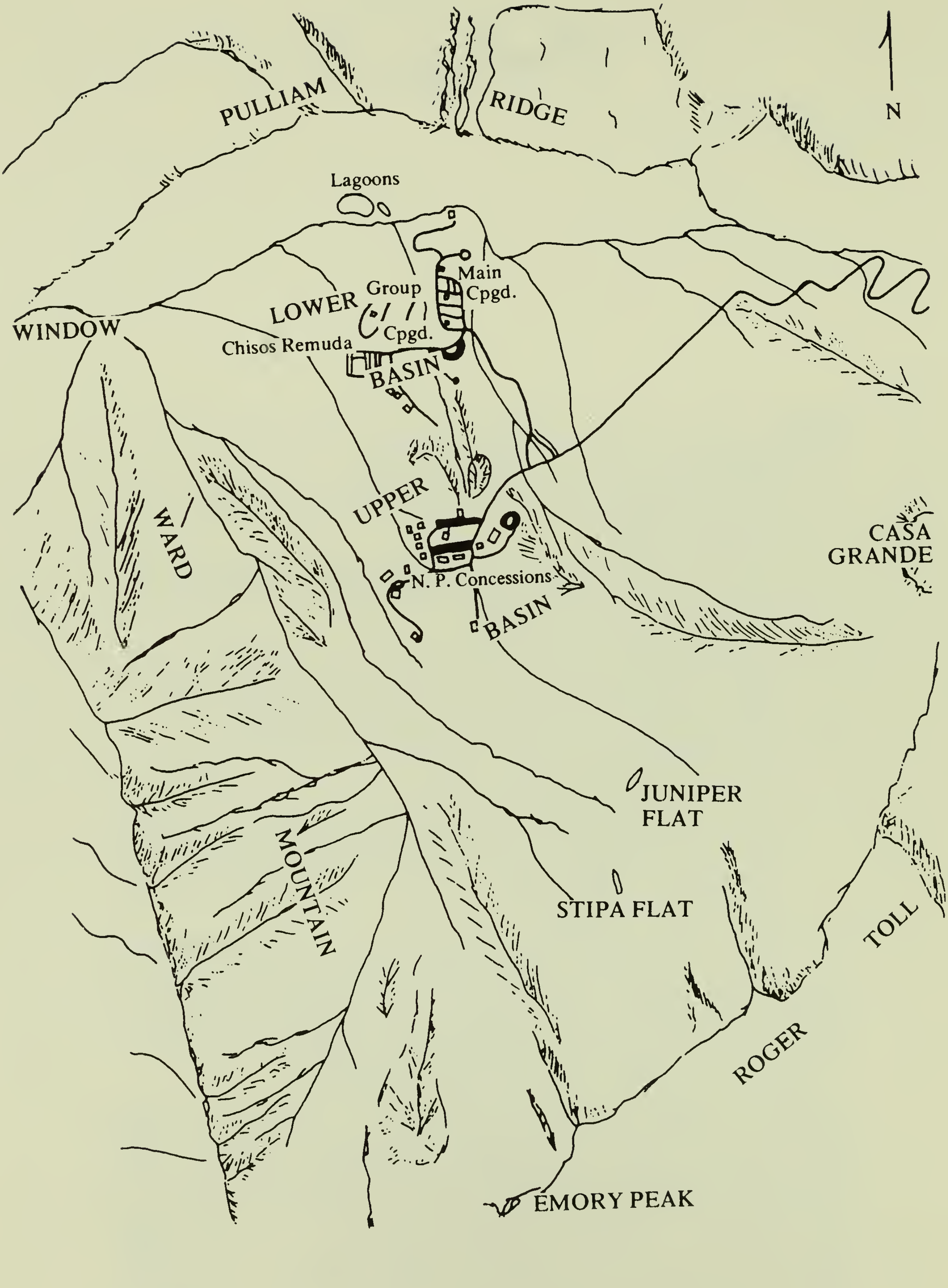


Fig. 1. Map of the Chisos Basin.

The present major uses of the basin consist of accommodating park visitors, concessions personnel, park personnel, and providing the visitors access to more remote regions of the mountains. Two concessions are located in the basin: the National Park Concession, Inc., which provides automobile, dining, and lodging services; and the Chisos Remuda, which provides horseback trail trips to the Window and South Rim. Campgrounds, Ranger Station, Campfire Circle, and the Trailhead for the mountain trail system are provided by the National Park Service.

Because of the large area, shortness of time, and a single field investigator, the major portion of this study was conducted in the northern half of the basin where the greatest degree of human impact is centered. The southern region of the basin was crossed on two occasions, but due to the great hiking distance, detailed investigations were not conducted. All of the field work was conducted in the month of August 1969, with a single week spent in late November. The laboratory work was conducted in the Plant Ecology Laboratories at the University of Oklahoma, Norman, Okla. Voucher specimens for the study are deposited in the Bebb Herbarium at the university. All plant names in the book follow Gould (1969). The field methods employed in the study follow standard vegetational sampling procedures and will be described in detail when introduced. Slight modifications were made for convenience and vegetational requirements. The census technique employed in the trail studies was developed by the author.

I wish to express my appreciation to the National Park Service for the opportunity to conduct this timely investigation (Contract # 14-10-9-900-196) and to the University of Oklahoma Research Institute for coordinating the project. Special appreciation is extended to Superintendent Luther Peterson, Chief Naturalist Roland Wauer, Maintenance Foreman Laurie Miller, and all other Big Bend National Park personnel for their able assistance and for providing pertinent information. I am indebted to Jimmy Massey for his field assistance, plant identification, and thought-provoking discussions and to his wife, Helen, for typing the progress and final reports. To my wife, Martha, I express sincere appreciation for assistance in preparation of the manuscript.

February 1973 PAUL D. WHITSON

1 Early Man's Use of the Mountains

One can only speculate on the history of early man in the Chisos Mountains and his effect upon the Chisos Basin and its vegetation. Man was certainly in the basin and nearby mountains prior to the invasion of the territory by the early 16th century Spanish explorers. Outstanding artifacts of early man are the mortars in Upper Juniper Canyon, middens at Laguna Meadow, and paintings at Stipa Flat in the basin, not to disregard the many stone points which have been found.

The "Big Bend Basket Makers," as they are usually referred to (Maxwell 1968), undoubtedly lived in caves, hunted game with darts, and used the native plants to weave baskets, sandals, and other objects. Their choice of *Nolina* (nolina) and *Dasylirion* (sotol) for weaving was probably the first major form of human impact upon the vegetation. Other fibers were probably used to a lesser extent. Certainly early man's effect upon the environment did not deviate significantly from that of the native fauna. Probably his activities were concentrated at or near springs, such as Kibbey Springs in the basin or at Boot Springs and Upper Juniper Springs higher in the mountains.

The earliest recorded report of man in the Chisos Mountains is that by the Governor of Coahuila, Don Pedro Rabago y Teran (Carroll), concerning his trip across the tip of Big Bend from Presidio del Sacramento to La Junta at the junction of the Conchos and Rio Grande rivers. In the report of crossing the Chisos Mountains in 1747, he tells of passing many Apache rancherias, both populated and abandoned. On 8 December 1747, his chaplain, Fray Manuel Neri, O.F.M., celebrated a mass in the mountains, and the party emerged from the Chisos Mountains on 14 December bound for Lajitas. Less than a week later Captain Fermin de Vidaurre, Commander of the Presido of Mapimi, followed Rabago's route through the Chisos Mountains and into Mexico at Lajitas.

The Indians encountered were probably of the Chisos tribe of the Apaches which dominated the area. Earlier reports by Alvar Nunez Cabeza de Vaca (1550s) and Antonio de Espeja (1580s) of the Indians in the region indicate a cultural shift to settlements and cultivation of corn, wheat, beans, maize, gourds, melons, and pumpkins along the streams (Maxwell 1968; Raht 1963). This practice may have reduced pressure upon the native vegetation for food, but promoted the growth of human and introduced plant populations.

With the white man's encroachment upon the Indian lands of the continent, the life of the Indians in the Big Bend region became more unstable. A major cause was the annual plundering forays by the Comanches from their northern rancherias into northern and central Mexico. The eastern branch of the Comanche Trail rose into the Chisos Mountains before crossing the Rio Grande at the "Great Indian Crossing" near the Coahuila-Chihuahua, Mexico boundary. This ravaging continued until 1845, when the U.S. government began serious exploration into the region. Accounts of the Comanche reign and its effects upon the smaller tribes suggest that the local tribes moved higher into remote areas, thus shifting their survival habits to hunting and gathering. Accompanying the Comanche reign were the increased activities of the Latin-American and Anglo-Saxon American outlaw bandits.

By the 1850s the Comanches had been controlled, and the major influx of European influence began in Big Bend country. Names such as John Love, T.W. Chandler, N. Michler, and W.H. Emory are found directing or leading mapping parties into the region; they often gave their names and those of others to topographic features. These trailmakers and the military men who followed soon afterward gave us the last reports of the nomadic, plundering Mescalero Apaches. The tribe spent spring and summer in the Chisos, Davis, and Guadalupe mountains and retreated to the upper Rio Grande during the Winter. Their last major fight for native lands was in 1881, when the Indian was finally conquered in Big Bend country.

2
European Man's Use of the Mountains and Basin

Ranching

The vast, open spaces of Big Bend, with miles of rolling grass, finally fell prey in the 1880s to the first major use of the vegetation when the ranching industry arrived with herds of longhorn cattle, Herefords, sheep, and goats.

On present-day parkland, the ranching industry had its developmental origins from 1882 to 1885 when the Estacado Land and Cattle Company, formed by General Gano and his two sons, acquired over 55,000 acres of land in the region. The spread ranged from Aqua Frio on the north to the Rio Grande on the south, and from Solitario on the west to the Chisos Mountains on the east. To care for the initial 6000 cattle, three line camps were established at Terlingua, Aqua Frio, and Chisos Springs. Chisos Springs, now called Oak Springs, became an important camp for the G-4 Ranch and those to follow. The operation disbanded in 1895, with over 17,000 cattle rounded up. That the operation was a successful venture is indicated by a maximum count in 1891 registering 30,000 head, only 5 years after a very dry year, 1885-86.

In the years that followed, a series of purchases and sales redistributed this and adjacent lands, but throughout the period Oak Springs remained important. In 1929 Homer Wilson purchased approximately 44 sections in the Oak Springs, Blue Creek, and upper mountain regions, including a part of the basin. By 1942 the Wilson ranch was estimated to control between 40,000-50,000 acres. The main line camp which supervised the cattle, sheep, and goat operations was in Blue Creek Canyon. The timbers used for the construction of the buildings came from the Chisos Mountains (Casey 1968).

Other ranchers in the area who had holdings in the mountains were: L. Wade, W. T. Burnham, and Sam Nail. Many other parties held claim to mountainous blocks or sections but ran no herds. Frequently, land use was leased or exchanged for other land.

The total impact of ranching upon the mountain area, and more specifically upon the basin, is extremely difficult to assess. A series of impressions may be obtained by reading Casey's history (1968) and the document files of the National Park Service.

Evidence generally indicates that the ranchers within the present park were professionally adept, not overstocking nor overgrazing their lands. The lands were used to their fullest capacity by some, however, with cattle, goats, and horses sharing the same range. This was necessary in some cases for a sound financial operation. Because most of the ranchers had long-range plans to remain in business at retirement or maintain family control, preservation of the range was of prime concern.

After the state of Texas purchased most of the privately owned lands in 1942, the ranchers were given free grazing privileges until actual creation of the Big Bend National Park in 1944. It was during this 3-year period that most of the range abuse occurred. There was general agreement among the ranchers themselves that during this time the ranges were greatly overstocked to take full advantage of the free grazing privileges. It is doubtful that had the ranchers intended to remain in operation on this land they would have allowed such large herds (Maxwell 1944). After having endured a drought in the mid-thirties, the effects of overstocking were greatly enhanced.

In the summer of 1944 over 40,000 head were grazed on parkland. Of these, 15,000 head were goats and 6000 were sheep (Maxwell 1947). Goats outnumbered other livestock in the basin because of their browsing habit and the steep terrain. Severe shrub damage was reported by McDougall (1953) at South Rim and Laguna Meadow. Maxwell (1944) reported that the basin had been quite heavily grazed during the past years, but for the last 2 years (1943-44) the grazing was limited to about 20-30 head of livestock.

Instances of severe grazing and the result of erosional problems are given for the lower desert in a report of Grazing Summary for Region Three (Big Bend National Park files). *Agave lecheguilla* (lechuguilla) and *Larrea tridentata* (creosotebush) increases are cited as effects of overgrazing. *Dasylirion* is reported to have been nearly eradicated in Green Gulch during the drought of 1918-19 when it was fed to cattle (McDougall 1953). Even though these changes are reported for lower elevations, they undoubtedly hold true in part for the entire basin area, but are not definitely cited.

Grazing and browsing pressure is still evident in the basin. The preponderant presence of *Xanthocephalum* spp. (broomweed) is one outstanding example. This plant has been found to increase greatly and persist for long periods of time after grazing (Cottle 1931). Another example is the large, dense stands of *Opuntia* sp. (prickly pear) along the base of Pulliam-Bailey ridges, not obvious in the area in 1935 (Warnock 1967). The two diverse forms of the older oak trees in the lower basin area are also signs of animal use: tall, single-trunked, high-crowned; or low, multi-trunked, with poor crown development. The first is the effect of browsing upon older trees and the second, of browsing on younger trees. Other possible effects of overgrazing are the broad expanses in the lower basin covered with *A. lecheguilla* and the many scattered stands of *Larrea tridentata* on erosional sites.

Prospecting and mining

Although there were never extensive mining operations in the Chisos Mountains proper, evidence of such activities can be seen. A rather large excavation can be viewed on the east side of Appetite Hill. L. Miller (pers. comm.) states that this was dug by Bud Kimbell and Cone Brown of Marathon between 1920-32. It seems that a fortuneteller in California predicted great riches could be found there. The riches were not found, but large quantities of fine soil have washed down to the flat to the north of the hill.

Smaller shafts are present along the contact of the igneous with limestone on the ridge to the northeast of Ward Mountain. These are very local in effect, however, because they are on steep slopes adjacent to washes.

Probably the greatest impact reported by this industry upon the vegetation is that described by Maxwell (1968). Because of the increasing demand for flammable materials to keep the Chisos Mining Company's cinnabar retorts fired at Terlingua, large quantities of timber were taken from Green Gulch and the basin in the early 1900s. How extensive this practice was is not known. I have searched for such activities in the form of stumps, trimming piles, and logs in both areas, but time seems to have eradicated any direct evidence. Only a few chopped stumps can be found. Because of inadequate roads for removal of timber, tree-felling would not seem to have been too extensive in the basin proper. The first reported road into the basin was constructed in 1934 when supplies were being hauled in for drilling the well to provide water for the proposed Civilian Conservation Corps camp in the basin (Casey 1948).

Civilian Conservation Corps

In 1933 Franklin D. Roosevelt approved the establishment of a C.C.C. camp in Brewster County. The two major sites proposed were in Green Gulch and the Chisos Basin, but because sufficient water could not be obtained in Green Gulch, emphasis was shifted to the basin. In April 1934, water was finally supplied by a well below the present campground. In May the first company arrived and established a camp above the well.

From this camp, which was later expanded, roads, buildings, and trails were constructed. These were directed toward providing facilities and developments for the Texas Parks Board which had created the Texas Canyons State Park and later Big Bend State Park. By 1938 state authority had granted permission to collect money for land purchases to the Big Bend National Park Association. Eventually, the state of Texas provided $1.4 million to secure private lands, which in 1943 were deeded to the National Park Service.

Most of the activity in the Chisos Basin during the 1930s was localized primarily in two areas: the Upper Basin, where the present Ranger Station and the National Park Concessions are located; and the Lower Basin, where the campground and Chisos Remuda are now situated. Remains of the C.C.C. camp can still be seen in the parking circle of the Campfire Circle. Old nails, metal objects, broken glass, and a concrete abutment are readily visible.

The projects of the C.C.C. camp completed before its abandonment in 1942 were: construction of stone cottages in the Upper Basin, 1935-38; completion and improvement of road into the basin, 1937; and construction of trails to Laguna Meadow, Window, and Juniper Flat, 1936-40; as well as the trail from Juniper Flat to Laguna Meadow Trail.

These projects resulted in complete removal of vegetation from the construction sites of trails, roads, buildings, and adjacent areas. They also made demands upon the area for building materials such as rock and soil. Drainage patterns were altered severely in many cases, thereby modifying vegetation growth. Along the many miles of roads and trails were signs of erosion and pathways by which disturbed area species advanced into new areas. The campground itself changed from a natural, vegetated area to a flat, hard-packed area with few native trees or shrubs. These projects created a demand for more improvements—a process which still continues.

It should be mentioned that even though the C.C.C. camp was in a state park, the Chisos Basin was still being grazed. One of the ranchers in the late thirties was Ira Hector (Warnock 1967).

Big Bend National Park

In 1944 the park was officially established, with headquarters in the basin. Within 3 years the two concessions were operating in the basin and making increased demands upon space and water supply. In 1947 another well was drilled, with a water tank soon installed above the present National Park Concessions residences, but was soon abandoned for lack of flow. By the end of the forties, activities were increasing greatly, and visitors were arriving in the basin on a newly paved road.

Improvements continued throughout the 1950s. The Upper Basin roads and parking lot were improved and paved in 1951. During the following year the Ranger Station was established, and the main water line from Oak Springs and the water barrel began to supply the increasing demand for water. A trail from Laguna Meadow to South Rim was added to the trail system in 1953. Much construction took place in 1958 and 1959 in the Lower Basin. Both the main and group campgrounds were built, including four comfort stations. The major sewer line was laid at this time. Adjoining the campground, the Campfire Circle and parking lot were constructed and paved along with the Lower Basin road.

The last decade saw expansion of the National Park Concessions in the form of two motel units (1960-65) and a lodge (1966). The National Park Service increased its buildings by adding four Ranger's residences (1962-64). To accommodate the increasing sewage, two lagoons were constructed in 1962.

A detailed analysis of the impact of the National Park Service and concessions upon the vegetation will be presented in detail, with supporting data, in Chapter 7.

3
Geological Considerations of the Basin

Structure and topography

The geologic structure of the Chisos Basin (Maxwell et al. 1967; Maxwell 1968) is comprised of a series of horizontal layers of Cenozoic-age volcanic ash, sandstone, conglomerate, and lava overlaying Cretaceous rocks. These two series were elevated by igneous intrusions during the Cenozoic Era. Erosion, sapping, and weathering eventually left resistant caps of lava and intrusive ridges which formed a hollow bowl. Rocks within the basin consist of Upper Cretaceous limestone (especially along the northern base of Ward Mountain), shale, and sandstone. In many areas the floor of the basin is composed of transported rock debris or gravel.

The resistant lava caps and intrusive domes create a very sheer, steep relief around the inner perimeter of the basin. These slopes are dissected and provide natural passes into the basin, such as Panther Pass and the Window. The drainage pattern is simple, with all of the debris and runoff from the basin eventually passing through Window. There are three major courses of heavy water flow, two of which meet just before entering Oak Creek to pass through the Window. One of these receives drainage from the Pulliam-Bailey and north basin region, while the other drains the Mt. Emory and east slopes of Ward Mountain. The third enters the latter and provides drainage for Roger Toll and areas south of Juniper Flat to the northern ridge extending from the base of Mt. Emory. A minor water path drains the Upper Basin complex from Casa Grande to Juniper Flat and eventually enters the Pulliam drainage near the Ward-Pulliam junction. The Pulliam-Bailey path drains the area which is most affected by man: the Upper and Lower Basin complexes.

Because of the steep terrain, large areas on the upper slopes are actively moving talus slopes. Some of these talus slopes have become stabilized and are covered with vegetation, while others are still in the process of stabilization. The many eroding ridges and the dissected floor of the basin have resulted in many different substrates, slopes, elevations, and aspects, thus providing a variety of habitats for the vegetation.

Soils

The soils of the West Texas mountains have been classified by Carter (1931) as belonging to the Brewster series. These soils, primarily derived from igneous parental material, are stony, noncalcareous, friable in texture, and range in color from red to red-brown. The soils of the Chisos Basin are complex because the parent materials are variable and were variously mixed during their erosion and transport. Because the topography is steep and complex, the distance of transport and degree of mixing resulted in localized differentiation. This differentiation has in turn been influenced by the vegetation and its role in soil-building.

For this study soils were collected at 18 sites (Table 1, Fig. 2) in conjunction with vegetation samples in order to determine soil-vegetation trends. The soil used

Table 1. Location and topographic characteristics of the sites sampled for soil and vegetation in the Chisos Basin.

Site No.	Site location	Exposure	Slope	Substrate[a]
1	300 ft above basin road, prior to crossing major ravine NE of Upper-Lower Basin Junction	WNW	19°	IR
2	600 ft above site 2, mid-slope of Casa Grande	WNW	34°	IR
3	Ridge extending to the NW of Casa Grande	NNE	36°	IR
4	Ridge extending to the NW of Casa Grande	SW	12°	IR
5	150 ft below basin road, midway between two major ravines NE of Upper-Lower Basin Junction	WNW	12°	IS
6	Flat at base of Pulliam Ridge, power line pass	S	17°	IS
7	100 ft from E base of Appetite Hill	NNE	10°	IR
8	200 ft from NE base of Appetite Hill	NNE	10°	IS
9	First limestone ridge NE base of Ward Mtn.	N	40°	L
10	Second limestone ridge NE base of Ward Mtn.	SW	40°	L
11	Middle of flat above junction of Ward-Pulliam drainage	W	3°	IS
12	Ridge to the E of flat above junction of Ward-Pulliam drainage	N	36°	IS
13	Ridge to the E of flat above junction of Ward-Pulliam drainage	S	26°	IS
14	Ridge to the S of Window View Trail below stone cottages	N	48°	IR
15	Ridge to the S of Window View Trail below stone cottages	S	20°	IR
16	150 ft E of stone cottages	N	26°	IR
17	250 paces below new trail section above Stipa Flat	N	16°	IR
18	Above old trail which leads off Boot Canyon trail above new trail sections below Pinnacles	N	26°	IR

[a]I = igneous, L = limestone, R = rough, unweathered, S = smooth, weathered.

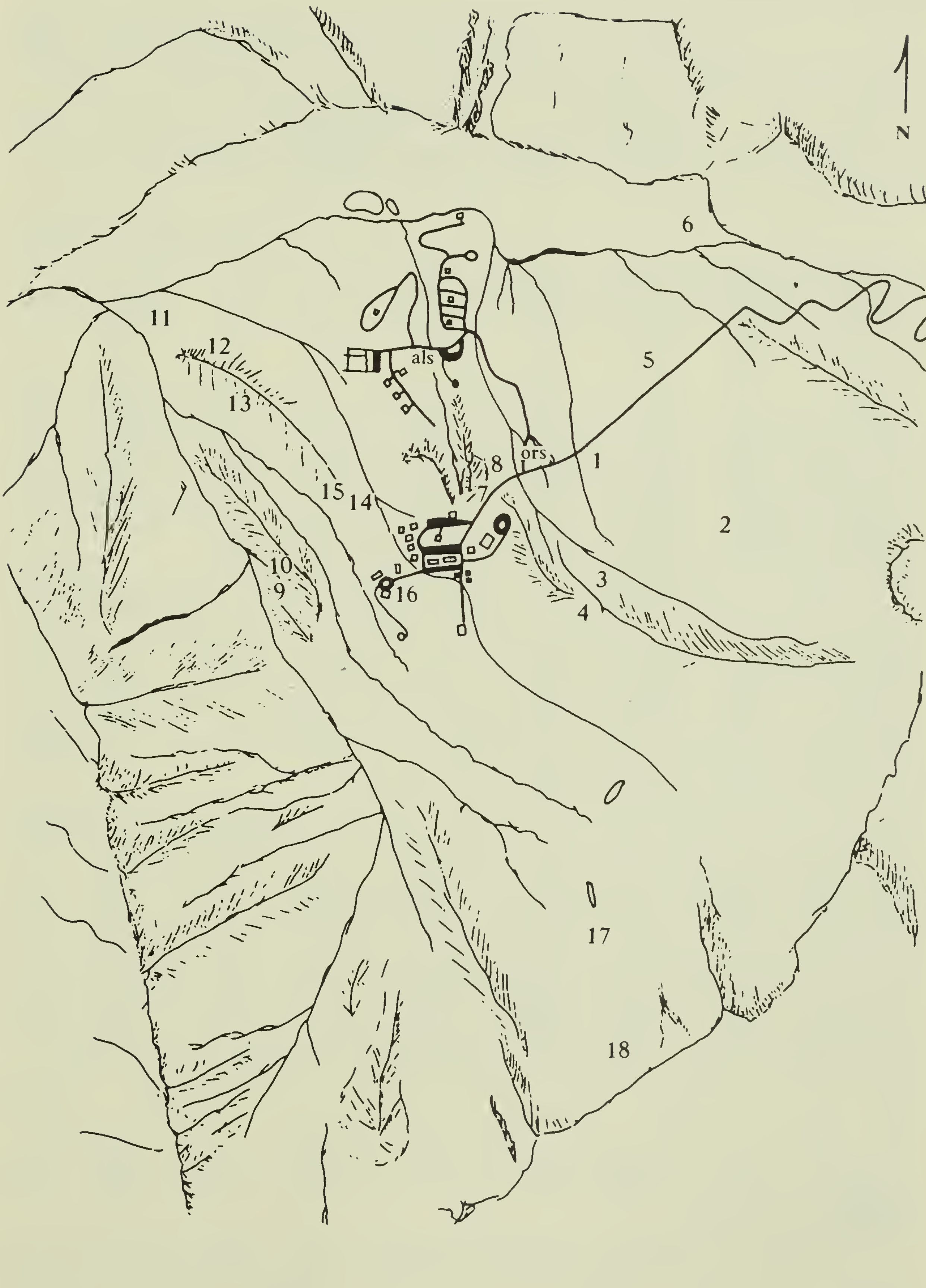


Fig. 2. Map of soil collection and vegetation sampling sites: ors, old road scar; als, *Aloysia lycioides* site.

in analyses represents a sample collected at the center of the vegetation transect from the 0 to 6-inch depth. At the time of soil collection, the percentages of rock (>22 mm), gravel (2-22 mm), and sand (<2 mm) were determined by sieving all excavated materials and weighing the particle classes to determine percentage of the total. Particle size is important in the damming effect it has upon runoff waters. The larger particles provide a greater damming effect, permitting the water to remain longer over a given area, thereby increasing infiltration and soil moisture.

The sand component of the excavated material was placed in paper bags and allowed to dry before storage. Upon return to Norman, Okla., the soil was sieved (2 mm) and transferred to an air-tight jar for storage. All analyses on the air-dried soil were based upon oven-dried equivalents and reported in terms of per cent per gram.

The pH was determined by the standardized glass-electrode procedure of Piper (1942). Texture was determined by the Bouyoucos method (Bouyoucos 1936). Total organic carbon was determined by the Walkley and Black method (Piper 1942). A gasometric method by Jackson (1958) was modified for quantification of calcium carbonate. Total phosphorus was determined by the method of Shelton and Harper (1941). In all cases duplicate samples were analyzed.

The results of soil analyses are presented in Tables 2 and 3. The site analyses are divided into the three major vegetation formations for presentation. All of the vegetation was rather distinct with respect to formation with the exception of sites 5, 8, 9, and 12. Because an attempt was made to acquire data on opposing exposures on similar soil types and at equivalent attitudes, several diverse and intermediate vegetation types were obtained. The above four sites fit this category; the first two because of impact, and the second pair because of exposure. They were then categorized by potential development.

The substrate from which the soils were derived was not important in contributing to soil color (Tables 1 and 2). The substrates can be grouped into three major types. Sites 9 and 10 were located on the Boquillas limestone at the northern base of Ward Mountain. A second substrate is composed of large, sharp, igneous rocks still in relatively organized position with respect to each other. These, evidently not greatly weathered stones, dominate sites 1-4, 7, and 14-18. The third substrate type consists of small, smooth, igneous rocks which show signs of great mixing and weathering. Sites 5, 6, 8, and 11-13 possess these. Neither the vegetation formations nor the soil-class types are confined to a particular substrate. The soil class, based upon texture, is no different for the vegetation formations and thus forms a mosaic distribution pattern. The third substrate type is more common at lower elevations in the basin, whereas the second type is common in Upper Basin and higher elevations.

The results of the chemical characteristics of the soils (Table 3) indicate trends with vegetation types, but only one outstanding correlation with substrate. On the limestone substrate, as would be expected, calcium carbonate was above 25% per gram in both sites. Soil pH increased as vegetation cover decreased or as a more xeric type was encountered. Calcium carbonate showed a similar trend even when the radical values were removed from the formation means. The amount of total

Table 2. Physical characteristics of soils sampled in the Chisos Basin.

Site no.	Soil color[a]	Particle distribution %/weight			Texture %/g			Soil class[b]
		Rock	Gravel	Sand	Sand	Silt	Clay	
Evergreen Woodland Formation:								
18	DG	80	4	16	72.4	17.4	10.2	SL
17	LB	26	48	26	66.4	20.4	13.2	SL
16	LGB	42	42	16	63.4	15.9	20.7	SCL
3	DG	53	20	27	71.4	16.0	12.6	SL
14	LB	65	22	13	46.9	16.0	37.1	SC
7	LB	66	20	14	69.4	9.5	21.1	SCL
1	LGB	46	36	18	71.9	14.5	13.6	SL
4	LB	40	36	24	72.4	15.5	12.1	SL
8	LB	17	44	39	54.4	18.2	27.4	SCL
5	LGB	18	50	32	67.9	16.0	16.1	SL
Average		45	32	23	65.6	15.9	18.4	SL
Chaparral Formation:								
2	DG	17	74	9	70.4	21.0	8.6	SL
9	LG	48	35	17	55.4	16.5	28.1	SCL
Average		32	54	13	62.9	18.7	18.3	SL
Chihuahuan Desert Formation:								
15	LGB	34	45	21	67.9	13.7	18.4	SL
11	LB	43	39	18	67.4	11.0	21.6	SCL
12	LYB	48	39	13	57.4	18.0	24.6	SCL
10	LG	48	31	21	64.9	17.0	18.1	SL
13	LGB	37	41	22	60.4	15.5	24.1	SCL
6	LB	47	33	20	74.9	15.5	9.6	SL
Average		43	38	19	65.5	15.1	19.4	SL
Others:								
ALS[c]	LGB	18	9	73	58.4	20.2	21.4	SCL
ORS[d]	LGB	28	40	32	67.4	12.4	20.2	SCL

[a]B = brown, D = dark, G = gray, L = light, Y = yellow.
[b]S = sandy, C = clay, L = loam.
[c]*Aloysia lycioides* site, south of Campfire Circle.
[d]Old road scar, near Upper-Lower Basin junction.

Table 3. Chemical characteristics of soils sampled in the Chisos Basin.

Site	pH	Carbon %/g	Calcium carbonate %/g	Phosphorus %/g
Evergreen Woodland Formation:				
18	6.7	11.70[a]	5.7	0.1020
17	6.3	1.55	6.9	0.0076
16	7.4	2.92	7.1	0.0260
3	6.7	2.42	7.9	0.0968
14	6.5	1.54	6.9	0.0093
7	6.1	2.45	6.7	0.0125
1	7.6	2.15	7.2	0.0244
4	6.4	1.14	7.2	0.1045
8	8.2[a]	0.13[a]	14.7[a]	0.0218
5	6.5	1.61	7.4	0.0169
Average	6.8 (6.6)	2.76 (1.97)	8.7 (7.0)	0.042
Chaparral Formation:				
2	7.2	7.07	7.2	0.0548
9	7.7	4.93	25.6	0.0470
Average	7.4	6.00	16.4	0.0510
Chihuahuan Desert Formation:				
15	7.7	2.61	8.6	0.0514
11	6.9[a]	1.31	6.7	0.0175
12	7.4	1.29	7.3	0.0152
10	7.9	1.88	57.6[a]	0.0570
13	7.8	2.18	8.6	0.0164
6	7.3	0.65[a]	7.3	0.0005[a]
Average	7.5 (7.6)	1.65 (1.85)	16.0 (7.7)	0.026 (.031)
Others:				
ALS	6.6	3.68	8.1	0.0680
ORS	8.1	0.70	10.3	0.0323

[a]Values omitted in calculating average in parentheses.

phosphorus is nearly double in the woodland compared to the desert although the values for each greatly overlap. The amount of total carbon is not significantly different between the woodland and desert formations, but greatly increases in the chaparral formation. This may be due to a more rapid and constant incorporation of plant material into the soil in the chaparral, as the leaves of the dominant chaparral plants are generally much smaller than those of the other two formations (Table 4).

More work on vegetation and soil relationships in the basin and park must be done before a pattern develops. Data to be discussed and included in this study will be an added component to this picture, but only for intermediate elevations.

Table 4. Summary of the dominant plants in the three formations in the Chisos Basin with their respective Importance Value. Generic names can be found in Table 6.

Site	Trees	Shrub-Succulents	Grasses	Herbs
Evergreen Woodland Formation				
18	*Q. gravesii* 71	*G. lindheimeri* 28	*P. fimbriatum* 6	*G. wrightii* 59
	J. flaccida 19	*S. regla* 15		*S. millelobatus* 17
17	*Q. emoryi* 47	*O. engelmannii* 13	*P. fimbriatum* 41	*C. eatoni* 7
	Q. gravesii 38	*N. erumpens* 11	*A. orcuttiana* 37	*X. microcephalum* 2
16	*P. cembroides* 78	*A. scabra* 24	*B. curtipendula* 83	*A. ludoviciana* 1
	J. deppeana 13	*O. engelmannii* 20	*A. orcuttiana* 20	
3	*P. cembroides* 37	*B. ternifolia* 21	*B. gracilis* 39	*A. ludoviciana* 68
	J. flaccida 14	*O. engelmannii* 12	*P. fimbriatum* 20	*X. microcephalum* 26
14	*P. cembroides* 37	*R. virens* 22	*B. curtipendula* 73	*X. microcephalum* 15
	Q. grisea 24	*Z. brevifolia* 22	*S. eminens* 28	*M. leucanthum* 5
7	*P. cembroides* 41	*C. montanus* 13	*B. curtipendula* 66	*C. mexicana* 17
	J. deppeana 33	*R. virens* 12	*B. barbinodis* 42	*C. eatoni* 6
1	*J. pinchoti* 30	*V. stenoloba* 25	*B. gracilis* 52	*E. modestus* 56
	P. cembroides 19	*O. engelmannii* 21	*B. curtipendula* 42	*X. microcephalum* 5
4	*Q. grisea* 11	*A. constricta* 36	*B. gracilis* 88	*E. wrightii* 18
		V. stenoloba 19	*B. curtipendula* 42	*X. microcephalum* 3
8	*J. pinchoti* 27	*O. engelmannii* 23	*B. curtipendula* 44	*X. microcephalum* 60
	P. glandulosa 19	*A. constricta* 16	*B. hirsuta* 39	
5	*P. glandulosa* 7	*A. constricta* 61	*B. gracilis* 102	*X. microcephalum* 19
		O. engelmannii 37	*B. curtipendula* 39	*E. greggi* 4

Chaparral Formation				
2	*Q. pungens* 24	*C. montanus* 44	*B. curtipendula* 48	*X. lucidum* 25
		V. stenoloba 40	*B. gracilis* 33	*S. millelobatus* 3
9	*Q. intricata* 10	*F. greggii* 55	*B. curtipendula* 24	*C. mexicana* 30
		Z. brevifolia 40	*A. glauca* 23	*X. microcephalum* 25
	Shrub	Succulents	Grasses	Herbs
Chihuahuan Desert Formation				
15	*R. virens* 51	*A. lecheguilla* 44	*B. curtipendula* 77	*C. pottsii* 15
	A. constricta 18	*D. leiophyllum* 7	*A. glauca* 41	*C. mexicana* 9
11	*V. stenoloba* 33	*A. lecheguilla* 69	*B. eriopoda* 72	*X. microcephalum* 14
	A. constricta 26	*O. engelmannii* 9	*B. curtipendula* 32	*C. mexicana* 2
12	*Z. brevifolia* 62	*O. engelmannii* 16	*B. curtipendula* 61	*P. alba* 14
	F. greggii 46		*A. glauca* 6	*X. microcephalum* 12
10	*F. greggii* 25	*A. lecheguilla* 70	*B. breviseta* 19	*M. scabra* 41
	G. spinescens 16	*D. leiophvllum* 20	*A. glauca* 4	*E. cinerescens* 36
13	*D. frutescens* 15	*A. lecheguilla* 91	*B. curtipendula* 87	*C. mexicana* 6
	M. biuncifera 15	*D. leiophyllum* 15	*A. glauca* 34	*M. leucanthum* 4
6	*Q. emoryi* 13	*A. lecheguilla* 52	*B. hirsuta* 77	*P. alba* 14
	V. stenoloba 6	*D. leiophyllum* 15	*S. scoparium* 65	*N. sinuata* 8

4

Climatological Considerations of the Basin

The climate of the Big Bend region is placed by Kendrew (1927) in a subtropical belt of high pressure which produces xeric climates. The seasonal high and low pressure centers over the Great Basin create the prevailing winds that influence Big Bend weather. The northerly winter winds produced by high pressures bring very little moisture to the region and only infrequent snow. The southerly, moisture-laden summer and early fall winds blow from the Gulf of Mexico and bring frequent, heavy rainfall to the cool, upper slopes of the mountains in the region. Typical of mountain regions, precipitation is of the convective shower type.

Long-range trend

In considering the role that climate has on vegetation, one must take into consideration both long-range and short-range cyclic trends. Martin (1963), using pollen analysis from Arizona sites, presents three major features of post-pluvial climatic history: an initial arid period climatically equivalent to the present and dating from 8000 to 10,500 B.P. (before the present); a less arid interval with intensified monsoon rainfall from 4000 to 8000 B.P.; and finally, an arid period closely resembling present conditions and lasting from 4000 B.P. to the present.

Data for the Chihuahuan Desert, and primarily from Big Bend National Park (Wells 1966), indicate a constant climatic condition from 36,600 B.P. to 11,560 B.P., using radiocarbon dating of vegetative materials from woodrat middens. Conditions became more xeric between 11,560 B.P. and 4200 B.P. as woodland species, such as *Pinus cembroides* (Mexican pinyon), *Juniperus pinchoti*, (redberry juniper), *Quercus pungens* (sandpaper oak), and *Celtis reticulata* (netleaf hackberry), present in the early middens, were excluded from the later middens at equivalent altitudes (1968 ft). Only xeric desert vegetation was found in the later middens, but was also present in the earlier middens along with the woodland species. The woodland, based upon its present lower elevational limits (4593 ft), has been shifted upward approximately 2624 ft since 11,560-14,800 B.P.

Several pertinent climatological studies cited by Hastings and Turner (1965) support the hypothesis that rainfall has been decreasing since at least the last half of the 19th century in the desert Southwest. There has been a notable decrease in winter precipitation and a slight decrease in summer moisture for areas in Arizona and New Mexico. Data presented by Schulman (1952) found a significant correlation between the amount of winter rainfall and growth in Big Bend National Park *Pseudotsuga menziesii* (Douglas fir). Since much fir growth occurs in the winter in response to winter precipitation, one wonders if the decreasing winter rainfall trend is affecting the growth of other mountain species in the park.

Accompanying the decreasing rainfall has been a worldwide warming trend

(Hastings and Turner 1965). Studies of rural area temperature records from Arizona from 1893 to 1959 indicate that the temperature records from May to October increased 2.4° F in comparing the period 1903-13 with that of 1930-40. For the 6 cold months, the increase amounted to 1.75° F. These results correlated significantly with other Southwest temperature data. Since a temporal increase of 3° F in mean annual temperature is equivalent to dropping approximately 900-1000 ft in elevation, the observed temperature increase could be of major significance to the vegetation. These increasing temperatures would tend to favor extension of xeric species to even higher elevations than would be expected. Superimposing such climatic information upon grazing and human activities, one can expect even greater elevational increases by the vegetation types.

Short cycles

One cannot discredit the effects that short cyclic climatological changes have on vegetation of Big Bend National Park. A reduction in grass cover and in other vegetation is reported for drought years 1885-86, 1918-19, mid-1930s, and 1951-56. During these periods, changes occurred which altered the vegetation for decades, perhaps even centuries. Such an example will be presented later for the park.

Since climatological data are readily available in summary form from the U.S. Department of Commerce (1968) for the period 1947-66 in the basin, it will be only briefly discussed. A few major points which should be made concerning the winter months are that the mean daily maxima for November, December, January, and February are 60-70°F while the minima are 37-47°F. On an average of 11 days, the daily maxima do not exceed 50°F. Rainfall averages less than the 0.75 inch per month and occurs on only 4 days in both December and January and on only 2 in February. The sparse snowfall-sleet averages 3.7 inches annually.

For the months from March to October the mean daily maxima range from 68 to 88°F, with the highest being in June. Mean daily minima range from 40 to 58°F, with the highest also being in June. A total average of 37 days can be expected above 90°F. Except for March and April, the rainfall averages greater than an inch for each month from May through October. July has the highest mean with 3 inches. The total annual average rainfall is 15.24 inches, with an average of 12.10 inches falling from May through October.

Included in the summary data for the basin is the record of one of the severest droughts since European man's entrance into the region. The drought began about July 1951 and lasted until September 1958. Conditions improved in 1957 and 1958 to annual averages of 16.80 inches from the previous 6 years' averages of 10.70 inches. These known drought years skew the 18-year average considerably. The average of the other 10 years (1949, 1950, 1959-66) is 17.92 inches, probably a more accurate annual average. Adding to these 10 years the totals for 1967 and 1968, the annual average is 18.26. This would be a difference of 7.56 inches less for the 6 severe years.

Communications with several persons living in the park during the drought indicate extensive deaths in the vegetation populations. McDougall (1953), after visiting the park in October 1953, states that oak trees were dying by the hundreds in Green Gulch, while pinyon pines and junipers were dying by the dozens. Similar deaths were reported for other species at desert elevations. Warnock (1967) reports similar information in his introduction. Certainly one cannot disregard the remains of many hundreds of trees seen from the trails in the basin.

A study conducted by Whitson (1965a,b) in Boot Canyon in 1964 presents an interesting response of the vegetation to the extended drought of the 1950s. The field work, conducted approximately 6-8 years after the end of the drought, showed a significantly high number of *Pinus cembroides* and *Juniperus deppeana* (alligator juniper) seedlings on the canyon floor where *Quercus gravesii* (Graves oak) trees were prevalent. He indicated that the more mesic oak vegetation was being replaced by a more xeric pinyon-juniper vegetation because very few oak seedlings were found. The evergreen seedlings were 4-6 years old at the time of the study.

Table 5 presents data for four permanent plots established in 1964 in the canyon and data collected in August for the same plots. At all plots the increase in *Q. gravesii* seedlings exceeded 100% of the 1964 census. *Quercus grisea* (gray oak) and *Pinus cembroides* increased by over 100% in one plot; however, *Q. grisea* showed the greatest percentage of death. Most of the new additions appeared to be from 1 to 3 years old. If the oak seedlings continue to grow, the original hypothesis of xeric replacement will be refuted. The data indicate that *P. cembroides* responded with great reproduction within 2-3 years after the drought, whereas *Q. gravesii* has required at least 10 years to respond. The recent additions of *Juniperus flaccida* (drooping juniper) and especially *Acer grandidentatum* (bigtooth maple) indicate perhaps a return to a more mesic time.

Table 5. Comparison of tree and seedling counts in four Boot Canyon permanent plots after a 5-year duration.

Species	1964 census	1969 census		
		Deaths	Additions	Total living
Trees:				
Cupressus arizonica	11	—	—	13[a]
Pinus cembroides	1	—	—	1
Quercus grisea	2	1	—	1
Quercus gravesii	3	—	—	3
Total	17	1	—	18
Seedlings-Saplings:				
Cupressus arizonica	18	—	—	16[a]
Pinus cembroides	124	9(7%)	36(29%)[b]	151
Quercus grisea	24	7(29%)	17(70%)	34
Quercus gravesii	81	7(8%)	147(181%)	221
Juniperus deppeana	30	3(10%)	8(26%)	35
Juniperus flaccida	—		1	1
Acer grandidentatum	—	—	1	1
Total	277	26	210	459

[a]Two saplings to tree category; dbh greater than 3 inches.
[b]Per cent of 1964 census.

5
Present Vegetation of the Basin

Methods

Since the vegetation of the Chisos Basin has not been previously investigated, this study attempted to sample and compare the vegetation on various substrates and on opposing exposures. Because of the rugged terrain and lack of time, only a cursory quantitative investigation could be made of the existing vegetation. Emphasis was placed upon the major vegetation types in the northern portion of the basin, where a total of 18 sites was sampled (Table 1, Fig. 2.).

The method used to sample the vegetation was to establish a line 100 ft long and record species and crown cover for every individual rooted or casting cover within 1.5 ft of the line. From these contiguous plots (10 x 3 ft) data were obtained which were used to calculate relative density, relative frequency, and relative cover values for each species. By summing the three relative values for each species in each transect, an Importance Value (IV) was obtained. This value permits the ranking of site species and was used in establishing the three formation classes.

A summary of the results for each site is presented in Table 4. The two dominant plants of each life-form in the three vegetation types are presented along with their IV. The sites are listed in each formation class from what is thought to be the most mesic to the most xeric. The life-form, generic name, common name, and a more complete list of the species are found in Table 6. The number of X's in a particular column is dependent upon the commonness of the species in the formation. One X indicates only sighting or collection in the formation, two signifies an IV of less than 40, and three, greater than 40. The list is by no means complete, but represents only those species sampled in transects or collected as vouchers in other studies. A total of 171 species is listed and over 300 specimens are deposited as vouchers in the Bebb Herbarium, University of Oklahoma, Norman, Okla.

The distinction of three formation classes is based upon the general physiognomy of vegetation, distribution, and species assemblages. More extensive field work in the mountains could reveal negation or added support. The three formations distinguished are: Evergreen Woodland Formation (EWF), Chaparral Formation (CF), and Chihuahuan Desert Formation (CDF, Fig. 3). A discussion of each formation will follow.

Table 6. Complete list of the plants encountered in the Chisos Basin study. The species, with common names, are grouped according to life-form and frequency in the formations (X, sighted or collected; XX, IV less than 40; XXX, IV greater than 40).

Species	EWF	CF	CDF
Trees			
Fraxinus cuspidata Torr. (Fragrant ash)	X		
Juniperus deppeana Steud. (Alligator juniper)	XX		
Juniperus pinchoti Sudw. (Redberry juniper)	XX		
Juniperus flaccida Schlecht. (Drooping juniper)	XX		
Arbutus texana Buckl. (Texas madrone)	XX		
Pinus cembroides Zucc. (Mexican pinyon)	XXX		
Quercus gravesii Sudw. (Graves oak)	XXX		X
Quercus emoryi Torr. (Emory oak)	XXX	X	XX
Quercus grisea Liebm. (Gray oak)	XX	X	X
Prosopis glandulosa Torr. (Honey mesquite)	XX		X
Quercus intricata Trel. (Dwarf oak)		XX	
Quercus pungens Liebm. (Sandpaper oak)		XX	
Celtis reticulata Torr. (Netleaf hackberry)			X
Acacia roemeriana Scheele (Roemer acacia)			X
Ungnadia speciosa Endl. (Mexican buckeye)			X
Diospyros texana Scheele (Texas persimmon)			X
Shrubs			
Forestiera neomexicana (New Mexico forestiera)	X		
Ceanothus greggi Gray (Desert ceanothus)	X		
Prunus serotina Ehrhart (Southwestern chokecherry) subsp. *virens* (Woot. & Standl.) McVaugh	X		
Aloysia wrightii (Gray) Heller (Wright aloysia)	XX		
Isocoma coronopifolia (Gray) Greene	XX		
Bouvardia ternifolia (Cav.) Schlecht. (Scarlet bouvardia)	XX		
Rhamnus betulaefolia Greene (Birchleaf buckthorn)	XX		
Salvia regla Cav. (Mountain sage)	XX		
Garrya lindheimer Torr. (Lindheimer silktassel)	XX	X	
Rhus aromatica Ait. (Skunkbush) var. *flabelliformis* Shinners	XX	XX	
Berberis haematocarpa Woot. (Red barberry)	X	X	
Larrea tridentata Cav. (Creosotebush)	X	X	XX
Viguiera stenoloba Blake (Skeleton goldeneye)	XX	XX	XX
Cercocarpus montanus Raf. (Silverleaf mountainmahogany) var. *argenteus* (Rydb.) F. L. Martin	XX	XXX	XX
Rhus virens Lindh. ex Gray (Evergreen sumac)	XX	XX	XXX
Zexmenia brevifolia Gray (Shorthorn zexmenia)	XX		

Table 6. (continued)

Species	EWF	CF	CDF
Aloysia lycioides Cham. (Whitebrush)	XX		X
Mimosa biuncifera Benth. (Catclaw mimosa)	XX		XX
Acacia constricta Benth. ex Gray (Mescat acacia)	XXX		XX
Condalia lycioides (Gray) Weberb. (Southwest condalia)	X		X
Condalia spathulata Gray (Knifeleaf condalia)	X		X
Ptelea trifoliata L. (Hoptree)	X		X
Parthenium incanum H.B.K. (Mariola)	X		X
Fraxinus greggi Gray (Gregg ash)		XXX	XXX
Glossopetalon spinescens Gray (Spiny greasebush) var. *mexicana* (Ensign) St. John		XX	XX
Ephedra nevadensis Wats. (Boundary ephedra) var. *aspera* (Engelm.) L. Benson			XX
Krameria glandulosa Rose & Painter (Range ratany)			XX
Dalea frutescens Gray (Black dalea)			XX
Leucophyllum minus Gray (Big Bend silverleaf)			X
Eysenhardtia texana Scheele (Texas kidneywood)			X
Vauquelinia angustifolia Rydb. (Slimleaf vauquelinia)			X
Baccharis glutinosa (Ruiz & Pavon) Pers. (Seepwillow)			X
Rhus microphylla Engelm. ex Gray (Littleleaf sumac)			X
Anisacanthus insignis Gray (Dwarf anisacanth)			X
Atriplex canescens (Pursh) Nutt. (Fourwing saltbush)			X
Sophora secundiflora (Ort.) Lag. ex DC. (Mescalbean)			X
Dicraurus leptocladus Hook. (Thinbush)			X
Succulent-Semisucculents			
Agave chisoensis C. H. Mueller (Chisos agave)	X		
Nolina erumpens (Torr.) Wats. (Foothill nolina)	XX	XX	
Agave scabra Salm-Dyck	XX	XX	
Dasylirion leiophyllum Engelm. (Smooth sotol)	XX	XX	XX
Opuntia engelmannii Parry (Engelmann pricklypear)	XX	XX	XX
Agave lecheguilla Torr. (Lechuguilla)			XXX
Opuntia imbricata Haw. (Cholla)			X
Opuntia kleiniae DC. (Candle cholla)			X
Opuntia leptocaulis DC. (Pencil cholla)			X
Grasses			
Cenchrus incertus Curtis (Sandbur)	X		
Eragrostis barrelieri Daveau. (Mediterranean lovegrass)	X		
Andropogon gerardi Vitm. (Big bluestem)	X		
Stipa eminens Cav. (Southwestern needlegrass)	XX		

Table 6. (continued)

Species	EWF	CF	CDF
Aristida orcuttiana Vasey (Single threeawn)	XX		
Aristida divaricata Humb. & Bonpl. ex Willd. (Poverty threeawn)	XX		
Stipa tenuissima Trin. (Finestem needlegrass)	XXX		
Piptochaetium fimbriatum (H.B.K.) Hitchc. (Pinyon-ricegrass)	XXX		
Eragrostis intermedia Hitchc. (Plains lovegrass)	XX	X	
Bouteloua gracilis (Willd. & H. B.K.) Lag. ex Griff. (Blue grama)	XXX	XX	X
Muhlenbergia emersleyi Vasey (Bullgrass)	XXX	XX	XX
Bouteloua curtipendula (Michx.) Torr. (Sideoats grama)	XXX	XXX	XXX
Bothriochloa barbinodis (Lag.) Herter (Cane bluestem)	XX	XX	XX
Aristida glauca (Nees) Walp. (Blue threeawn)	XX	XX	XX
Lycurus phleoides H.B.K. (Wolftail)	X	X	XX
Setaria macrostachya H.B. K. (Plains bristlegrass)	XX		X
Hilaria mutica (Buckl.) Benth. (Tobosagrass)	XX		X
Muhlenbergia rigida (H.B.K.) Kunth. (Purple muhly)	XX		XX
Sorghum halpense (L.) Pers. (Johnsongrass)	X		X
Bouteloua hirsuta Lag. (Hairy grama)	X		XXX
Schizachyrium scoparium (Michx.) Nash (Little bluestem)			XXX
Heteropogon contortus (L.) Beauv. (Tanglehead)			XX
Bouteloua breviseta Vasey (Chino grama)			XX
Bouteloua eriopoda (Torr.) (Black grama)			XX
Panicum hallii Vasey (Halls panicum)			X
Panicum obtusum H.B.K. (Vinemesquite)			X
Bromus unioloides (Willd.) H.B.K. (Rescuegrass)			X
Cynodon dactylon (L.) Pers. (Bermudagrass)			X
Muhlenbergia porteri Scribn. (Bush muhly)			X
Erioneuron pulchellum (H.B.K.) Tateoka (Fluffgrass)			X
Erioneuron grandiflorum (Vasey) Tateoka (Large flowered tridens)			X
Sporobolus cryptandrus (Torr.) Gray (Sand-dropseed)			X
Leptochloa dubia (H.B.K.) Nees (Green spangletop)			X
Panicum bulbosum H.B.K. (Bulb panicum)			X
Aristida ternipes Cav. (Spidergrass)			X
Digitaria californica (Benth.) Henr. (Arizona cottontop)			X
Chloris virgata Swartz (Showy chloris)			X
Echinochloa crusgalli (L.) Beauv. (Barnyardgrass)			X
Herbs			
Conyza sophiaefolia H.B.K. (Leafy conyza)	X		
Heliopsis parvifolia Gray (Mountain heliopsis)	X		
Euphorbia villifera Scheele (Hairy euphorbia)	X		
Pellaea intermedia Mett. ex Huhn (Creeping cliffbrake) var. *pubescens* (Mett.) Brown	X		
Ximenesia encelioides Cav. (Golden crownbeard)	X		
Euphorbia strictospora Engelm. (Slimseed euphorbia)	X		

Table 6. (continued)

Species	EWF	CF	CDF
Cissus incisa (Nutt.) Des Moulins (Ivy treebine)	X		
Phanerophlebia umbonata Underw.	X		
Phoradendron bolleanum (Seem.) Eichler (Rough mistletoe)	X		
Eriogonum wrightii Torr. (Wright wildbuckwheat)	XX		
Cheilanthes eatoni Baker (Eaton lipfern)	XX		
Perezia nana Gray (Desertholly perezia)	XX		
Aletes acaulis (Torr.) Coult. & Rose (Stemless aletes)	XX		
Lonicera albiflora T. & G. (Bushy honeysuckle) var. *dumosa* Gray	XX		
Senecio millelobatus Rydb. (Manybract groundsel)	XX		
Artemesia ludoviciana Nutt. (Sagwort) var. *albula* (Wooten) Shinners	XXX		
Erigeron modestus Gray (Plains fleabane)	XXX		
Galium wrightii Gray (Rothrock bedstraw) var. *rothrockii* (Gray) Ehrendorfer)	XXX		
Eriogonum hemipterum (T. & G.) Stokes (Wildbuckwheat)	X	XX	
Hedyotis fasiculata (Bertol.) Small (Cluster bluet)		XX	
Pellaea microphylla Mett. ex Kuhn. (Littleleaf cliffbrake)		XX	
Ipomopsis aggregata (Pursh) V. Grant (Skyrocket ipomopsis) var. *texana* (Greene) Shinners		X	
Xanthocephalum lucidum Greene (Sticky snakeweed)		X	
Xanthocephalum microcephalum (DC.) Shinners (Threadleaf snakeweed)	XX	XX	XX
Chrysactinia mexicana Gray (Damianita)	XX	XX	XX
Melampodium leucanthum T. & G. (Plains blackfoot)	XX		XX
Bommeria hispida (Mett.) Underw. (Hairy bommeria)	XX		X
Eupatorium greggi Gray (Palmleaf eupatorium)	XX		X
Machaeranthera pinnatifida (Hook.) Shinners	X		X
Tribulus terrestris L. (Puncturevine)	X		X
Alternanthera peploides (H. & B.) Urban (Mat chaff-flower)	X		X
Solanum elaeagnifolium Cav. (Silverleaf nightshade)	X		X
Croton pottsii (Klotzsch.) Muell. Arg. (Leatherweed croton)	X		XX
Euphorbia cinerescens Engelm. (Ashy euphorbia)			XX
Notholaena sinuata (Lagasca) Kaulf. (Cloakfern) var. *integerrima* Hook.			XX
Polygala longa Blake (Narrowleaf milkwort)			XX
Polygala alba Nutt. (White milkwort)			XX
Hedyotis polypremoides (Gray) Shinners			XX
Menodora scabra Gray (Smooth menodora) var. *laevis* (Woot. & Standl.) Steyermark			XX
Brickellia veronicaefolia (H.B.K.) Gray (Brickellbush) var. *petrophila* B. L. Robinson			XX
Notholaena sinuata (Lagasca) Kaulf. (Bulb cloakfern) var. *sinuata*			XX
Polygala scoparioides Chod. (Broom milkwort)			X
Marrubium vulgare L. (Common horehound)			X
Croton fruticulosus Engelm. (Bush croton)			X
Boerhaavia coccinea Mill. (Scarlet spiderling)			X

Table 6. (continued)

Species	EWF	CF	CDF
Sphaeralcea angustifolia (Cav.) D. Don. (Globemallow)			X
Porophyllum scoparium Gray (Poreleaf)			X
Baileya multiradiata Harvey & Gray (Desert baileya)			X
Senecio longilobus Benth. (Threadleaf groundsel)			X
Conyza canadensis (L.) Cronquist (Horseweed) var. *glabrata* (Engelm. & Gray) Cronquist			X
Clematis drummondii T. & G. (Texas virgins bower)			X
Tetraneuris scaposa (DC.) Greene (Plains tetraneuris) var. scaposa			X
Rivina humilis L. (Bloodberry)			X
Xanthocephalum sarothrae (Pursh) Shinners (Broom snakeweed)			X
Notholaena aurea (Poir.) Desv. (Slender cloakfern)			X
Notholaena standleyi (Star cloakfern)			X
Teucrium laciniatum Torr			X
Mirabilis albida (Walt.) Heimerl. (White four-o'clock) var. *albida*			X
Amaranthus palmeri Wats. (Palmer amaranthus)			X
Peganum harmala L. (Harmal peganum)			X
Hymenoclea monogyna T. & G. (Burrobush)			X
Salsola kali L. (Russianthistle) var. *tenuifolia* Tausch			X
Chamaesaracha coronopus (Denal) Gray (Green false-nightshade)			X
Berlandiera lyrata Benth. (Greeneye)			X
Janusia gracilis Gray (Slender janusia)			X
Selaginella arizonica Maxon (Arizona selaginella)			X
Dyschoriste linearis (T. & G.) Ktze. (Narrowleaf dyschoriste)			X
Brickellia californica (T. & G.) Gray (Brickellbush)			X
Cyphomeris gypsophiloides (Mart. & Gal.) Standl. (Red cyphomeris)			X
Trixis californica Kellogg (American trixis)			X

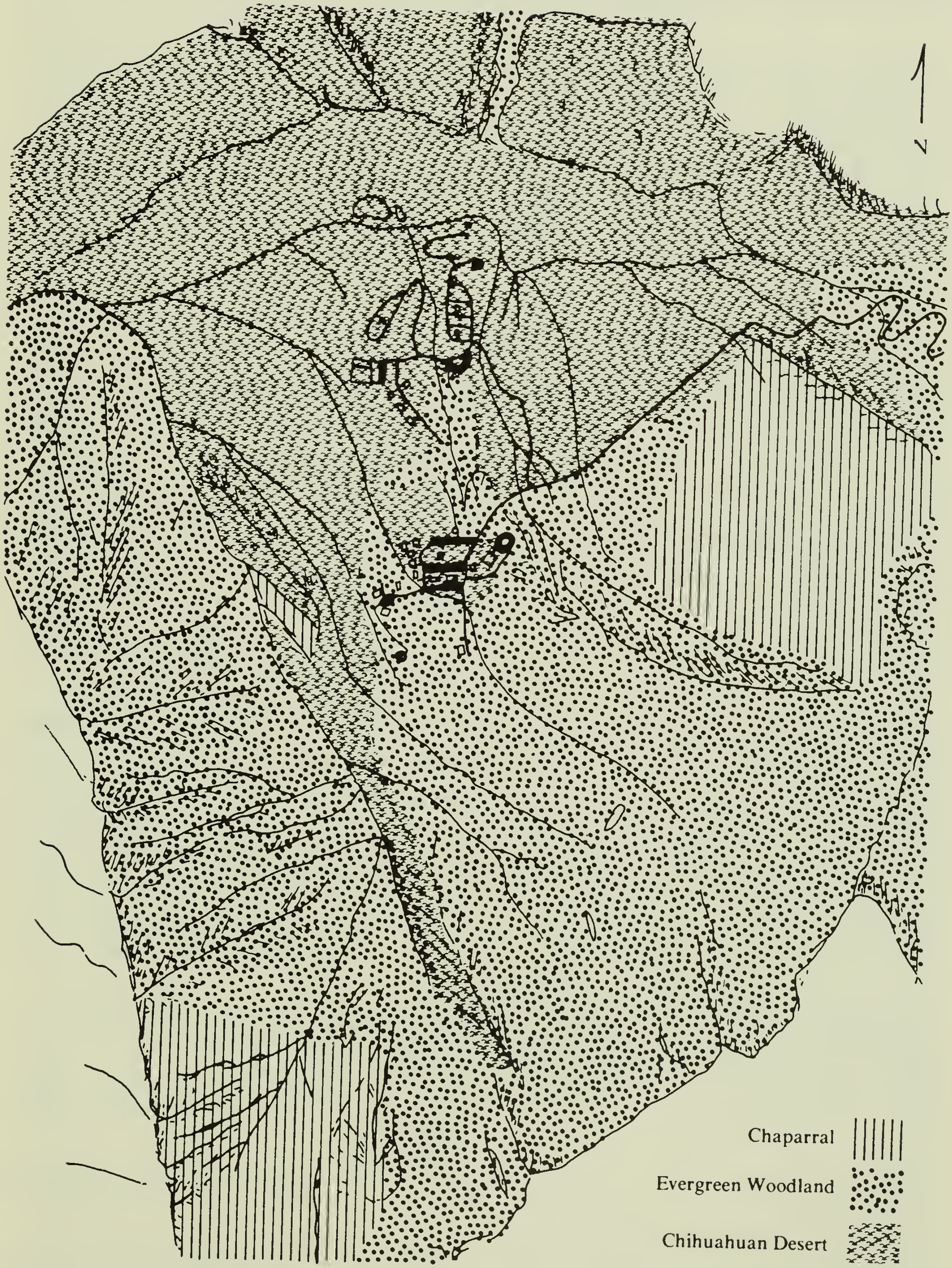


Fig. 3. Map of present vegetation in the basin.

Evergreen Woodland Formation

The Evergreen Woodland Formation is a rather distinct formation throughout the southwestern mountains (Gehlbach 1966). The formation is dominated by rather broadly spaced trees up to 25 ft high. Frequently, a space of a crown diameter may occur between individuals where an abundance of grass and/or shrubs develop. Three distinct height layers are evident: trees, shrubs, grasses-herbs. The formation occupies rather mesic slopes with northern exposures at lower elevations (4000-5500 ft) in the Chisos Mountains and on most exposures above 5600 ft.

The dominant trees of this formation in the basin (Table 4) are both evergreen and deciduous in character. The deciduous oak, *Quercus gravesii*, is the most moisture-dependent of the group and attains great prominence higher in the moist canyons of the Chisos Mountains. A second deciduous oak, *Quercus emoryi* (Emory oak), is adapted to more xeric conditions at intermediate elevations and is associated with *Q. gravesii* at the latter's lower limit. An evergreen oak, *Q. grisea*, is most common on very xeric slopes at elevations below *Q. emoryi*. Associated with these broadleaf trees are four narrowleaf evergreens: *Pinus cembroides*, *Juniperus deppeana*, *J. flaccida*, and *J. pinchoti*. The latter is the more xeric or low elevation species, whereas the other three are intermediate to mesic. *Prosopis glandulosa* (honey mesquite) is the most common introduced tree to invade this formation in the basin. This species is not common at elevations above 5600 ft.

Common shrubs-succulents of the mesic, upper slopes of the formation are *Garrya lindheimeri* (Lindheimer silktassel), *Salvia regla* (mountain sage), and *Nolina erumpens* (foothill nolina). *Opuntia engelmannii* (Engelmann pricklypear), *Agave scabra* (Agave), *Cercocarpus montanus* (true mountainmahogany), and *Bouvardia ternifolia* (scarlet bouvardia) are intermediate and more widely distributed. At lower elevations *Rhus virens* (evergreen sumac), *Viguiera stenoloba* (skeleton goldeneye), *Acacia constricta* (mescat acacia), and *Zexmenia brevifolia* (shorthorn zexmenia) are common. *Acacia constricta* and *Opuntia engelmannii* are the most common shrub-succulent invaders of the basin. The former is common to ravines in the lower desert region.

The most common grass of the formation is *Bouteloua curtipendula* (sideoats grama); however, at higher elevations *Piptochaetium fimbriatum* (pinyon-ricegrass), *Muhlenbergia emersleyi* (bullgrass), *Stipa tenuissima* (finestem needlegrass), *Stipa eminens* (southwestern needlegrass), and *Aristida orcuttiana* (single threeawn) can be locally dominant. *S. tenuissima* is the grass most frequently encountered in flats such as Juniper Flat, Stipa Flat, and the flat at the north end of the ridge extending northward from the base of Mt. Emory. At the lower limits of the formation *Bouteloua gracilis* (blue grama), *B. curtipendula*, and *Muhlenbergia rigida* (purple muhly) are common. Invaders of the formation primarily at lower elevations are *Bothriochloa barbinodis* (cane bluestem), *Bouteloua hirsuta* (hairy grama), *Eragrostis intermedia* (plains lovegrass), *Aristida glauca* (blue threeawn), *Setaria macrostachya* (plains bristlegrass), and *Hilaria mutica* (tobosa).

There is a large group of herbs which is found in the formation. The most dominant species are *Xanthocephalum microcephalum* (threadleaf snakeweed) and *Artemesia ludoviciana* (Louisiana sagewort), which have become broadly distributed because of intense grazing and disturbance in the formation. A common invader at lower elevations is *Chrysactinia mexicana* (damianita), an exceedingly odiferous plant. At higher elevations *Cheilanthes eatoni* (Eaton lipfern), *Senecio millelobatus* (manybract groundsel), and *Galium wrightii* (Wright buttonweed) are frequent components of the formation.

As shown in Fig. 3, the Evergreen Woodland Formation is primarily confined to northwest-northeast slopes in the basin. Small stands can develop at the base of sheer cliffs on southern exposures and in canyons, such as the stand in Pulliam Ridge to the north of the campground. In this canyon other highly mesic species are found, such as *Phanerophlebia umbonata*, *Aquilegia longissima* (longspur columbine), *Acer grandidentatum*, and *Rhamnus betulaefolia* (birchleaf buckthorn). Along small suture lines, talus margins, and small ravines on northern Ward Mountain and Pulliam Ridge, formation representatives are established.

On upper southern exposures within the formation, the vegetation shifts to species which dominate the Chihuahuan Desert Formation. *Fouquieria splendens* (ocotillo), *Dasylirion leiophyllum* (smooth sotol), and *Agave lecheguilla* are common examples. Site 15 exemplifies a low elevation and a southern exposure which can be compared with site 14 on a northern exposure at the same elevation. At a still higher elevation is site 3 on a northern exposure and site 4 on a southern exposure which has shifted to grassland shrub.

The lower margin of this formation in the basin has been the region of most human activity and as a result has lost much of its true woodland character. Sites 8 and 5 demonstrate this best, for in this area the dynamics has been shifted by man to favor the vegetation of the desert formation. An indication of the shift to xeric vegetation is the unusual density which *Acacia constricta*, *Xanthocephalum* spp., and *Opuntia engelmannii* have attained. Evidence that the area should be woodland is the number of isolated large pinyons, junipers, and oaks throughout the area. Accompanying many of these trees are small clumps of the woodland grass *Muhlenbergia emersleyi*.

Dynamics of the formation throughout its range indicates that all of the trees are reproducing well except in the human-impacted areas. Climatic conditions seem to be adequately supporting their comeback from the drought of the fifties. Unfortunately, the rate of reproduction in the impacted Lower Basin environs do not show this surge (Tables 11 and 18).

Chaparral Formation

The Chaparral Formation is a physiognomically distinct formation, but is quite variable throughout the Southwest. Wells (1965) reports an evergreen chaparral vegetation at higher elevations in the Dead Horse Mountains in the park. The formation is dominated in the basin by rather dense populations of trees and shrubs, seldom exceeding 5 ft in height. Only one height layer is distinct; however, in more sparse areas, grass can be important. The formation appears on two substrates in the basin. The first is the upper talus west slope of Casa Grande, which is igneous in origin, whereas the second area is on limestone at the northeast base of Ward Mountain. The formation reaches its greatest development on limestone to the northwest of Laguna Meadow on eastern Ward Mountain.

The dominant trees of the formations are *Quercus pungens* and *Q. intricata* (dwarf oak), but small stunted individuals of *Q. grisea* and *Q. emoryi* can also be found on the middle slopes of Casa Grande. *Quercus intricata* is evergreen while *Q. pungens* is deciduous.

Evergreen shrubs are the primary components of the formation. On the igneous slope the common shrubs are *Cercocarpus montanus*, *Viguiera stenoloba*, and *Rhus aromatica*, while *Nolina erumpens* and *Agave scabra* are present as succulents-semisucculents. On the limestone exposure *Fraxinus greggi* (Gregg ash), *Zexmenia brevifolia*, and *Glossopetalon spinescens* (spiny greasebush) are important shrubs. Succulents-semisucculents are of much less importance, but are represented by *Opuntia engelmannii*, *Agave scabra*, and *Dasylirion leiophyllum*.

Grasses are locally important in the formation, *Bouteloua curtipendula* being the most prevalent on both substrates. On the igneous substrate *Bouteloua gracilis* is of secondary importance, as is *Aristida glauca* of the limestone substrate. Of the herbs *Xanthocephalum* spp. are most common, while on the limestone *Chrysactinia mexicana* is prominent.

Figure 3 shows the Chaparral Formation to be confined primarily to the middle and upper slopes of Casa Grande and to northern exposures of the limestone ridge at the northeast base of Ward Mountain. The formation needs much further investigation into its extent and dynamics. The vegetation has close affinities with the Chihuahuan Desert Formation and on southern exposures shifts to components such as *Agave lecheguilla*, *Dasylirion leiophyllum*, and occasionally *Larrea tridentata*, a species of the Shrub Desert Formation. An example of this is the comparison of site 9 with site 10 (Table 4). Unfortunately, data from other studies are not available to consider the effects of human use; however, *Xanthocephalum* spp. may be examples of such activity. The Casa Grande slopes are very unstable and may account for its prevalence here; however, grazing has probably created greater instability. Because of the stunted *Quercus grisea* and *Q. emoryi* trees, this area may have been woodland, as the northern exposures would suggest.

Chihuahuan Desert Formation

The Chihuahuan Desert Formation is a distinct formation throughout the foothill region of the Chihuahuan Desert (Gehlbach 1966). The formation is dominated by low-leaf succulents or semisucculents with shrubs and/or grass locally. The two distinct height layers present are those of 1-3 ft for succulents-grasses and 2-5 ft for shrubs. The formation in the basin is limited to very xeric, rocky, southern exposures, although at lower elevations (2-4000 ft) there is little exposure restriction.

The dominant succulents-semisucculents of the formation are *Agave lecheguilla*, *Opuntia engelmannii*, and *Dasylirion leiophyllum* (Table 4). All are leaf succulents except for *O. engelmannii* which has stem succulence. All are adapted to very xeric conditions, with *O. engelmannii* being the most broadly distributed and the most common invader of the mesic upland.

The shrubs most common in the formation are *Rhus virens* (evergreen sumac), *Acacia constricta, Viguiera stenoloba, Fraxinus greggi, and Zexmenia brevifolia.* Found in localized areas are *Glossopetalon spinescens, Dalea frutescens* (black dalea), *Mimosa biuncifera* (catclaw mimosa), *Aloysia wrightii* (Wright aloysia), and *A. lycioides* (whitebrush). In areas which are highly disturbed or eroded, *Larrea tridentata* is present. Along the ravines in this formation, shrubs such as *Eysenhardtia texana* (Texas kidneywood), *Vauquelina angustifolia* (slimleaf vanquelina), *Anisacanthus insignis* (dwarf anisacanth), and *Aloysia lycioides* are common. Most of the shrubs are microphyllus and deciduous.

The grasses which are restricted primarily to the Chihuahuan Desert Formation are *Heteropogon contortus* (tanglehead), *Bouteloua breviseta* (chino grama), *B. eriopoda* (black grama), *Schizachyrium scoparium* (bluestem), and *Muhlenbergia porteri* (bush muhly). Several grasses common to the formation which are also found throughout the mountains are *Bouteloua curtipendula, Bothriochloa barbinodis, Bouteloua gracilis, Aristida glauca, Muhlenbergia emersleyi, and Lycurus phleoides* (wolftail). *Bouteloua breviseta,* the most dominant species at lower elevations in the park, is an unimportant species in the basin. *Bouteloua curtipendula, Heteropogon contortus, Panicum obtusum* (vine mesquite), and *Sporobolus cryptandrus* (sand dropseed) are common invaders into disturbed areas of the formation.

A large group of herbs is found in the formation. Tables 4 and 6 present many of those encountered in the study. It is of interest that most herbs are of little importance in the formation. Many of them, with the exception of *Xanthocephalum* spp., *Chrysactinia mexicana,* and *Melampodium leucanthum* (plains blackfoot), are relatively small in size. The first two are common invaders following heavy grazing and are not consumed by livestock.

Because the formation is confined to southern exposures (Fig. 3), it is relatively restricted to Pulliam Ridge, Vernon Bailey, and southern slopes below the Upper Chisos Basin. Small isolated areas develop within the other two formations on extremely xeric exposures. An example of the shift on opposing slopes is shown by site 12, a northern exposure, and by site 13, a southern exposure, both at low elevations north of Ward Mountain. The northern exposure is very similar to chaparral, except that few evergreen shrubs and oaks are present. A study of the relationship between the two formations should be undertaken in the Chisos Mountains.

The dynamics of this formation has been investigated (Whitson 1970) in conjunction with the Shrub Desert Formation at lower elevations throughout the park. Based upon low elevation trends, the Chihuahuan Desert Formation probably expanded greatly in the basin during grazing pressure and the following drought. Although *Agave lecheguilla* cannot compete with dense grass cover, it can invade when the cover is reduced.

Additional data to support the expansion are a series of new photographs by Warnock (1967). A site along the base of Pulliam Ridge, originally photographed in 1935 and duplicated in 1966, exhibited an increase in *Opuntia engelmannii* and grasses such as *Heteropogon contortus* and *Bouteloua eriopoda*. *Quercus grisea* decreased noticeably. A second site, a view of Mt. Emory from the base of Pulliam Ridge, indicated an increase in *O. engelmannii*, *Acacia constricta*, *Rhus virens*, *R. aromatica*, and *Juniperus pinchoti*. The new photographs did not specifically demonstrate *Agave lecheguilla*; however, the increase in *O. engelmannii* and *Acacia constricta* would indicate formation expansion. The higher importance of grasses at all sites sampled, with the exception of one site, tends to substantiate the fact that no appreciable expansion is presently occurring. Small *Agave lecheguilla* individuals were not common at the sampled sites. Determination of the long-range trend must await future investigations. Concern and observation must be given to the advancement of the formation, since a lengthy span of time is required before woodland vegetation can reinvade an area controlled by the desert vegetation.

Summary and comparison

The three vegetation types are distinctive in physiognomy due to the different strata that predominate in each. Accentuating the strata are the different life-forms of the dominant species. In the Evergreen Woodland Formation, oak, pinyon, and juniper trees dominate, with shrubs and grasses being subordinate; while in the Chaparral and Chihuahuan Desert Formation, shrubs and grasses dominate the physiognomy of the vegetation. Both formations have low-growing life-forms, but differ significantly in their leaf-form. The desert vegetation exhibits leaf succulence with a reduction in stems, except *Opuntia engelmannii* with a succulent stem and reduced, ephemeral leaves, while the Chaparral vegetation has extensive stem systems and nonsucculent leaves. The leaves of this vegetation type are frequently broad evergreen or microphyllus.

The importance of these characteristics is allied with their origin and evolution with respect to climate. The woodland vegetation has many counterparts which developed in the northern temperate, mesic highlands from Arcto-Tertiary Geoflora, while the chaparral and desert vegetation have counterparts in the Madro-Tertiary Geoflora (Axelrod 1950, 1958, 1959). This flora developed in the southern temperate lowlands under arid conditions. These diverse origins, along with the prevailing climate in the basin toward aridity, favor those species with high physiological tolerance for low moisture. This is extremely evident in vegetation dynamics since many more desert vegetation species are found in the Evergreen Woodland and Chaparral Formations, while few of their species are found in the Chihuahuan Desert Formation.

Other examples of these factors are evident when comparing formations with respect to individual densities and vegetation cover. An average of 273 individuals occurred in the Chihuahuan Desert Formation transects, whereas 129 and 193 occurred, respectively, in the Chaparral and Evergreen Woodland Formations. The average percentage of cover for all transects in each formation, in the order presented above, was 50 (43-62), 68 (63-71), and 79 (51-110) percent. This demonstrates that there are many small individuals comprising the desert vegetation, while in the woodland, where stratification is important, there are fewer large individuals. Chaparral vegetation was intermediate with respect to these values.

6

Hypothetical Vegetation of the Basin

This topic is a most difficult one to assess, but necessary to confront if one is to assess the role of human impact. The major problem is to determine whether man's influence is a single factor which must be included in the sum of ecosystemic dynamics, or whether it has an additive or compounding effect upon one or several factors. Because there are no documented natural factors of extreme effect such as fire, fungal diseases, pestiferous infestations, unusually high native animal populations, faulting to effect hydrology, etc., since European man's influence, only climate needs to be superimposed upon man's impact.

In considering climate there is little information available. Droughts of short duration are recorded, but the majority were of little consequence to the vegetation as a whole. Droughts which lasted for a year reduced forage grasses, but had little effect on sheep or goat browse. The drought of the fifties, following the cessation of grazing, created a major problem because the effects of the drought were accentuated by the impoverished state of the vegetation at the time. The drought began only 6 years after grazing ceased, making assessment of vegetation recovery from grazing difficult. McDougall (1953) reports that vegetation recovery by 1953 for the Chisos Mountains was rapid; for instance, the grasses on the South Rim were probably in as good a condition as before grazing. Unfortunately, nothing was stated concerning the Chisos Basin but, because of its elevation, the condition of the basin vegetation was not as improved as that higher in the mountains. This is implied from conditions described by McDougall for lower areas in the park.

I can see continued improvement in the Boot Spring to South Rim region from 1964 to the present, indicating that the condition on South Rim today is superior to that of 1953. This then makes McDougall's report of rapid vegetation recovery quite difficult to accept, as either the vegetation was very poor during his first visit (1943-45) or the condition deteriorated greatly between 1953 and 1964. The latter could certainly have occurred, since 3-5 years of drought ensued. The question then arises: Were the conditions worse after a 6-year recovery from 14 or more years of grazing-browsing or after a 13-year recovery from a 5- to 7-year drought? I tend to accept the former explanation, because even after the added effects of good moisture and no grazing since the drought, one still finds many areas poor in natural vegetation composition. This seems to negate the concept that vegetation can recover rapidly in a 5-7 year period.

If a similar reasoning can be applied to basin conditions, but at a slower pace of improvement due to more human activity, vegetation conditions improved little prior to the drought and thus compounded the effect of the drought. Such a hypothesis cannot be proved or substantiated because of the lack of extant data. The case is ecologically sound for, 13 years after the drought or 24 years since grazing ceased, one finds areas of the basin still in very poor condition. The area in point is a triangle, one side being a line drawn from the junction of Pulliam Ridge-Ward Mountain drainage to a ravine south of National Park Concessions prefabs; a second drawn from the prefabs to the Panther Pass parking lot; and the final side following the drainage along the base of Pulliam Ridge to Ward Mountain junction. All transects sampled in this area (sites 1, 5, 7, 8, and 11) had vegetation of a hybrid or disturbed nature except for site 7. On the basis of results of this study, this condition is due to man and his livestock.

Predrought grazing in the basin had its greatest effect by reducing grass cover and density, thus permitting the first major invasion of desert herbs, shrubs, and succulents and the beginning of the soil moisture-nutrient depletion, erosion cycles, and the loss of the natural vegetation's competitive edge. Since all of these factors could not be corrected in 6 years, the drought supported the trend initiated by the overgrazing. Unfortunately, the invasion plants were of xeric origin, possessed long life-spans, and were maintained by small disturbances which permitted them to control the area at the expense of natural grasses and woody plants. The presence of the xeric plants delayed vegetation recovery and development and excluded grasses which promote soil nutrition, moisture, stabilization, structure, and reduced runoff. Without these improvements the drought supported establishment of the Chihuahuan Desert Formation plants at the expense of Evergreen Woodland Formation components.

The construction of Fig. 4, which presents the hypothetical distribution of vegetation, essentially involved the addition to the Evergreen Woodland Formation to those areas which are hybrid or disturbed in nature. Evidence that the area would be woodland were it not impacted is the occasional large trees and small seedling-saplings which occur in the region. In small microclimates on some northern exposures along ravines, very highly developed woodland vegetation is present, including grasses and shrubs in some instances.

The species composition of the Evergreen Woodland Formation would not include in any great number such invaders or disturbed area species as *Xanthocephalum* spp., *Chrysactinia mexicana*, *Opuntia engelmannii*, *Prosopis glandulosa*, and *Acacia constricta*. Species occurring in the woodland such as *Viguiera stenoloba*, *Artemesia ludoviciana*, *Bothriochloa barbinodis*, *Bouteloua curtipendula*, *B. gracilis*, and *Juniperus pinchoti* would also be of lower importance. *Quercus grisea* and *Q. emoryi* would be of greater importance as trees in the lower basin area. Accompanying the oaks and various woodland grasses would also be woodland shrubs, especially along the ravines of the lower basin, now dominated by desert shrubs.

The Chihuahuan Desert Formation in the basin would be of the sotol-grass association type with some scattered oaks and *Agave scabra*, rather than the lechuguilla-grass association which presently dominates large areas. On isolated areas

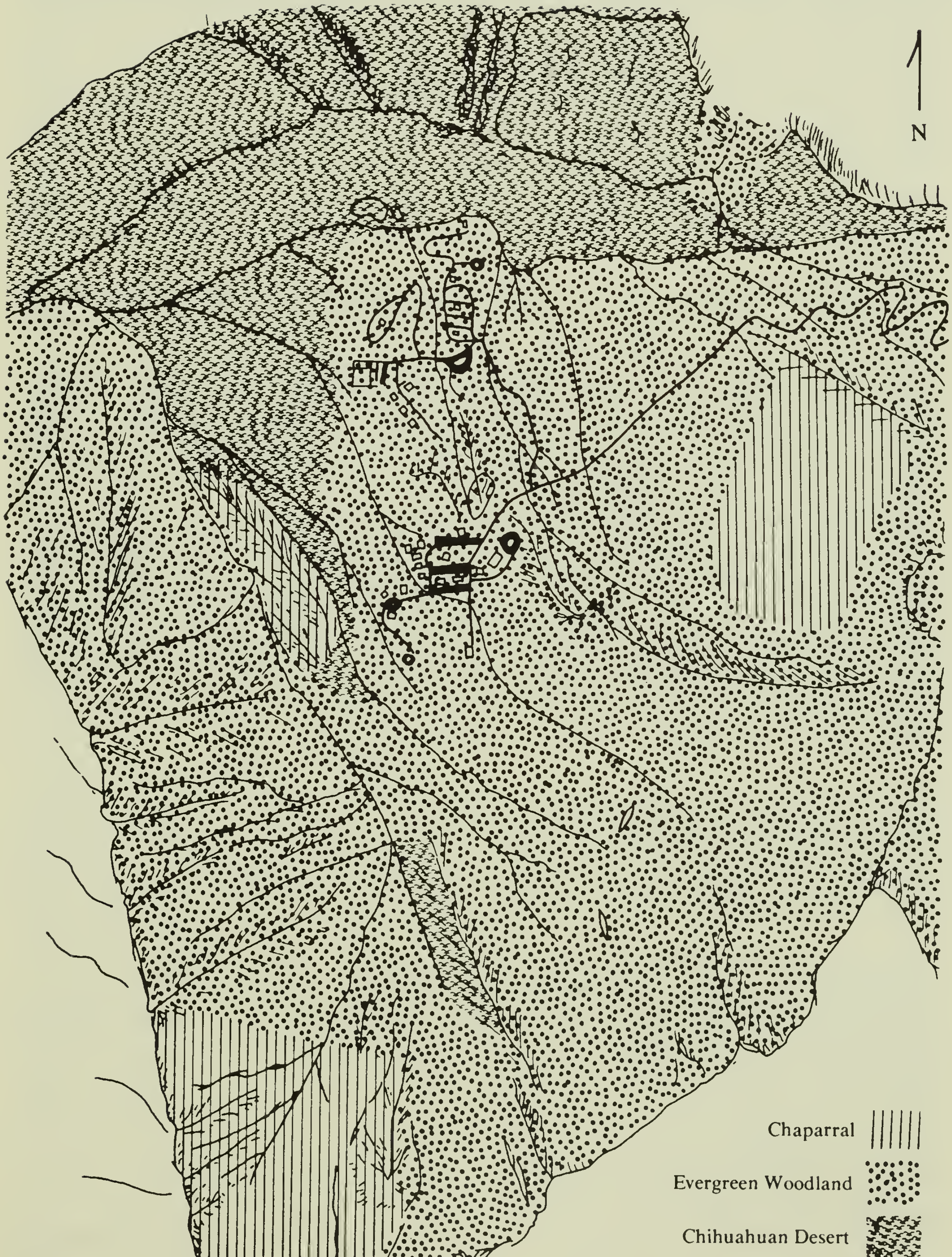


Fig. 4. Map of hypothetical vegetation in the basin.

of the more xeric exposures lechuguilla-grass would still occur, but the grasses would predominate. Low elevation invader species such as *Larrea tridentata, Erioneuron pulchellum* (fluffgrass), *Aristida glauca*, and *Heteropogon contortus* would not be of their present importance. The following lowland species would not be expected to occur in the basin at all: *Atriplex canescens* (fourwing saltbush), *Opuntia kleiniae* (candle cholla), *O. leptocaulis* (pencil cholla), *Parthenium incanum* (mariola parthenium), *Baileya multiradiata* (desert baileya), *Machaeranthera pinnatifida*, *Hilaria mutica*, and *Erioneuron grandiflorum* (large flowered tridens). These species are currently present in the campground and adjacent areas.

The effect of grazing upon the Chaparral Formation is more difficult to analyze. *Quercus grisea* and *Q. emoryi* would be, at present, of much greater importance on the upper slopes of Casa Grande, while *Xanthocephalum* spp. would be much lower in importance in this area. *Agave lecheguilla*, *Larrea tridentata*, and *Aristida glauca* would not be expected to occur on the limestone substrate, while *Quercus intricata* and *Fraxinus greggi* would be of greater importance on the southern exposures than they are presently.

The area to the northeast of the campground would resemble vegetation at sites 7 and 16 which are presently dominated by pinyons, junipers oaks, and grass (Table 4). Below the campground and Chisos Remuda would be a vegetation dominated by grass, with scattered gray oaks and pinyons especially along the ravines. The lower slope of Pulliam Ridge would again be dominated by grass, gray oaks, and scattered sotol and pinyons.

7
Present Impact Upon the Basin Vegetation

Definition and ecology

This section will present the ecology of the Chisos Basin with examples of impact that presently occur and affect the vegetation. It should be reemphasized that certain of the impacts have been in effect for many years as presented in Chapter 2. However, neither the total ecology nor all examples of impact are included. Those examples included were obvious, at least partially understood, measurable, and thought to demonstrate impact. The science of human impact ecology, exclusive of pollution and grazing studies, is relatively new. In this study, methods which I felt a priori would demonstrate impact were used. Several of these methods proved to be inadequate, but will be presented with their criticisms. Many new sampling techniques and methods of impact recognition must be developed before adequate experimentation can ensue. Another difficulty in this study is that cumulative data from major basic studies on the soil, vegetation, and vegetation dynamics are not presently available.

Herein, impact will be considered any human activity which directly alters or interferes with the vegetation or natural factors acting upon the vegetation. Not included are those indirect factors such as increased carbon dioxide, carbon monoxide, pesticides, light, temperature, and wind currents which could indeed be included by definition and are real in effect.

The generalized pattern of impact or disturbance upon vegetation is that of removing or contributing to the reduction or alteration of existing vegetation. This generally results in bare areas or in a less complete vegetation type, with cover, number of plants, and number of plants species all being reduced. This backward step, frequently called a disclimax, is essentially the opposite of succession, which leads ultimately to the most stable, mesic, and complex vegetation, the climax. The degree of vegetation removal determines the magnitude of the backward step. Unfortunately, in the basin most impact results in completely denuded sites, frequently accompanied by upheaved soil. In the upheaved condition an appreciably greater time is required for revegetation because soil microorganisms, air, temperature, nutrients, and moisture capacity have been greatly altered. Also, the lack of vegetation cover and roots results in decreased organic material and increased light penetration.

The impacted site, depending upon the desires of man, may be left bare, covered by structures, may undergo continual compaction, or be left for ''nature'' to revegetate. With the exception of the first, the alternatives leave a new site to be conquered by "nature." The site can now be referred to as a disturbed area into which only a few species of plants are capable of invading. These invaders must be capable of rapid growth, have great tolerance for high light intensity, high temperature, low moisture, low humidity, low nutrients, and other harsh conditions. If the species is successful, the site conditions are ameliorated, allowing a succession of less tolerant species to invade.

The vegetational cycle in the Chisos Mountains seems to be initial invasion by several herbaceous plants. These plants are then followed by succulents, shrubs, and finally trees. Table 7 presents a few of the native species found to be involved in succession in Evergreen Woodland-Chihuahuan Desert Formations. The length of this first stage is not known, but based upon the plants present in the main waterline scar produced in 1952, it lasts at least 15-18 years. This is because grasses are still dominant in the scar. The only shrubs-succulents which are just beginning to enter the scar are *Dasylirion leiophyllum*, *Mimosa biuncifera*, and *Opuntia engelmannii*. This is in the Chihuahuan Desert Formation section of the scar.

Table 7. Important native invaders of disturbed areas in the Chisos Basin.

Evergreen Woodland Formation	Chihuahuan Desert Formation
Herbs and grasses:	
Bouteloua curtipendula	*Bouteloua curtipendula*
Bouteloua hirsuta	*Aristida glauca*
Bothriochloa barbinodis	*Heteropogon contortus*
Xanthocephalum spp.	*Bothrichloa barbinodis*
Artemesia ludoviciana	*Xanthocephalum* spp.
Erigeron modestus	*Erioneuron pulchellum*
Perezia nana	*Setaria macrostachya*
	Sphaeralcea angustifolia
	Panicum hallii
	Croton pottsii
	Chloris virgata
Shrubs, succulents, and trees:	
Prosopis glandulosa	*Prosopis glandulosa*
Opuntia engelmannii	*Opuntia engelmannii*
Mimosa biuncifera	*Dasylirion leiophyllum*
Acacia constricta	*Mimosa biuncifera*
Chrysactinea mexicana	*Acacia constricta*
	Viguiera stenoloba
	Parthenium incanum
	Agave lecheguilla
	Larrea tridentata

Frequently accompanying these native herbaceous plants into the area are exotic species introduced from the Old World which have finally made their way into the basin. These include: *Sorghum halpense* (Johnsongrass), *Cynodon dactylon* (Bermudagrass), *Bromus unioloides* (rescuegrass), *Salsola kali* (Russianthistle), *Tribulus terrestris* (puncturevine), *Marrubium vulgare* (common horehound), *Peganum harmala* (harmal peganum), *Echinochloa crusgalli* (barnyardgrass), and *Eragrostis barrelieri* (Mediterranean lovegrass).Others which are native but of a "weedy" nature are *Solanum elaeagnifolium* (silverleaf nightshade), *Cenchrus incertus* (coast sandbur), and *Alternanthera peploides* (mat chaff-flower).

One of the most important aspects of the cycle is that once the shrubs begin invasion, they may remain as individuals for 60-100 years; such is the case for *Larrea tridentata*, *Prosopis glandulosa*, and *Acacia constricta* (Shreve and Hinckley 1937). There is strong evidence that *L. tridentata* (Went 1955) and *P. glandulosa* (Sankhal et al. 1965) are capable of producing inhibitory substances which prevent establishment of other species for long periods of time. Abdul-Wahab and Rice (1967) present similar evidence for such inhibitory activity by *Sorghum halpense*, an abundant species in impacted areas in the basin.

Further discussions of the ecology and effects of the specific forms of impact will be presented under each example. In several cases the sequence deviates from the generalized pattern and must be considered separately. The sequence of examples is not intended to be a rank of their degree of impact.

Forms of present impact

Roads

One of the earliest forms of basin impact, other than grazing, was that of road construction. The first roads in 1934 were dirt, but these were later paved in 1948 and 1958. The two types of roads undoubtedly vary in effect, but information on the extent of impact is not available. Besides the original denuding of the vegetation, impairment of natural drainage by blockage or rerouting is pertinent. The road fill, if taken from a distant area, provides an opportunity for importation of new species and new denuded sites to be occupied. The fill soil can vary so greatly that local native vegetation is extremely slow to invade. Road cuts, made to provide local fill, cause extensive erosion sites and in conjunction with the road shoulder provide miles of continual disturbance. These areas provide constant avenues for new species' invasion. Since the roads have been paved, surface rain runoff has greatly increased on some shoulders, resulting in increased vegetation growth.

The unusually dense thickets of *Aloysia lycioides* that have developed east of the road to the north and south of the Campfire Circle indicate impairment of drainage here. Road tiles are absent or nonfunctional in two instances. Soil analyses (Tables 2 and 3) from the *A. lycioides* stand south of the circle demonstrate a damming effect, since the texture (total sand, silt, clay) of the smaller particles is higher with respect to gravel and rock. The soil displays this characteristic as well as higher carbon and phosphorus values, typical of transported soils. The sites which provide the nearest control values for comparison are sites 5 and 7.

Closely correlated with drainage is excess runoff. The most unusual example is the area to the west or below the Ranger Station near the Trailhead. All the water from the Upper Basin parking area and above flows into this region, resulting in excess moisture and transported soils which support extensive populations of *A. lycioides*. Much of this runoff would normally flow to the ravine behind the Service Station or remain in the downfall area. The Lower Basin exhibits other such examples in and around the group campground circle and along the north and northwest margin of the main campground. Also increasing at an alarming rate along the road to the east of the main campground is *Sorghum halpense*. On the road fill and ravine floor to the north of the campground are large, well-established clones.

The effect of road cuts and their erosion sites are best exemplified along the switch backs into the basin below Panther Pass, at the entrance into the Upper Basin complex, behind the lodge, and along the road to the pumphouse below the main campground. The latter two are in need of immediate control.

The role of road margins as disturbed areas was investigated along the Upper Basin to Lower Basin road. Every 50 paces, from the junction to near the main campground, 14 line-intercept transects perpendicular to and alternating from side-to-side of the road were sampled. Coverage, to the nearest inch, was recorded for each species touched by the line from the edge of the asphalt to the line's end. This end point was determined to be where the vegetation remained stable in composition when compared to that traversed. Usually the transects were 16-20 ft long, with the first 4-6 ft being the more barren shoulder or drainage path, and that beyond the shoulder, the natural vegetation.

The results indicate that the shoulder had a total vegetation cover of 28.6%, whereas that beyond the shoulder had 82.4%. The latter area is less disturbed by erosion or denuding by blading. The following species contributed the respective percentages to the shoulder cover: *Bothriochola barbinodis, 26; Bouteloua curtipendula*, 19; *Viguiera stenoloba*, 17; *Larrea tridentata*, 10; *Bouteloua gracilis* and B. eriopoda, 8; *Parthenium incanum*, 6; *Xanthocephalum microcephalum*, 4; *Setaria macrostachya*, 2; and *Sphaeralcea angustifolia* (narrowleaf globemallow), 1. It is of interest to note the absence, addition, and shift in per cent of those beyond the shoulder: *Xanthocephalum microcephalum*, 21; *Acacia constricta*, 20; *Viguiera stenoloba*, 13; *Bouteloua curtipendula*, 10; *B. gracilis* and B. eriopoda, 8; *Rhus aromatica*, *Opuntia engelmannii*, and *Trixis californica* (American trixis), 3.

The absence of *Bothriochloa barbinodis*, *Setaria macrostachya*, *Larrea tridentata*, *Parthenium incanum*, and *Sphaeralcea angustifolia* is significant since the latter three are most common at lower elevations in the park. The first two frequent disturbed areas in the basin. The species in the natural vegetation do not deviate significantly from site 5 (Table 4) nearby. The natural vegetation cover percentage is also very similar to the site which had a total plant cover of 92%. The major deviation is the reduction in grass, probably due to the greater growth of shrubs along these roads from greater runoff.

A major factor contributing to the high importance of desert species along the road is the desert origin of the road fill. It has many desert characteristics, including its color. *Larrea tridentata* size and distribution also substantiate the soil's desert origin, with most being on road fill and from 9-15 years of age, near the 1958 improvement date.

Other evidence to substantiate the desert origin of road fill is the old road scar to the northeast of the present Upper to Lower Basin junction. Table 8 presents the Importance Percentages (IP—average of the sum of the species relative density and relative cover) of the species sampled across this road scar. The transect was a series of contiguous linear quadrats 10 ft long and 3 ft wide. Quadrats 4, 5, and 6 are the old scar, with the remainder being natural vegetation. Soil data (Tables 2 and 3) correlate most closely with the other desert vegetation soils in having high pH and calcium carbonate and low carbon and phosphorus.

It is significant that the species in the second group in Table 8, composed of those occurring in the scar and natural vegetation, are all invaders of disturbed areas in the basin. Both *Agave lecheguilla* and *Dasylirion leiophyllum* may have been planted in the scar as their clone sizes are quite large for the available growth time, 11 years. The planting of such desert species by the National Park Service seems to be a general practice, even in the basin.

Table 8. Importance percentages of the species in an old road scar in the Chisos Basin.

Species	Transect quadrats								
	1	2	3	4[a]	5[a]	6[a]	7	8	9
V. stenoloba	9								
A. lycioides		15							
B. eriopoda								29	69
J. pinchoti									19
B. hirsuta	63	8					14		6
B. curtipendula	3	12	20	20	16	35	32	6	3
B. barbinodis	18	8	57	24	3	23			
A. constricta	7	47	6	16		33	43	4	
O. engelmannii		10	17		4	4	19	39	
X. microcephalum					11		11	21	
A. lecheguilla				19	22				
L. tridentata				15	6				
E. intermedia				6	8	5			
D. leiophyllum					5				

[a]Quadrats which are the road scar.

The line-intercept method used along the road is an adequate method to obtain qualitative differences, but is rather insensitive to quantitative differences in the vegetation. It was learned from the sampling of this section of roadside vegetation, in conjunction with sites 5 and 8, that the entire northern basin region is composed of a highly disturbed vegetation type. This disturbed condition decreased the sensitivity of the method for comparing impacted vegetation with nonimpacted or natural vegetation. Contiguous plots, which could give added density data, would be a recommended alternative method rather than the line-intercept.

Trails

The most widespread form of basin impact is that of the trail system, which traverses many steep slopes and vegetation types. The effects are similar to road impact as the native vegetation is removed, creating bare areas and impairing natural drainage. The trails, however, lack a complex fill since they are carved from the natural slope. This may impact root damage to nearby trees and shrubs, but does not necessarily result in immediate physical removal or death. The carving process creates, on both sides of the trail, disturbed margins of a xeric nature. The upslope surface is generally hard and steep, while the downslope side is soft and steep. These erosive margins provide many continuous miles of varied habitats for new species.

The rockiness, tree roots, steep terrain, and rainfall runoff require extensive use of drainbars to stabilize such trails. The drainbars in turn create many different vegetative microclimates, where many fine soils and organic materials accumulate and increase their size with every downpour of rain. Because the trails have a soft surface, their maintenance must be greater than that of the paved roads. The method of upkeep can very rapidly influence the trails' overall impact. Important to the trails are the organisms which use them; in this case, man, his horses, and native wildlife.

Throughout the trail system, the organisms' effect upon the natural drainage systems can be observed. This is most readily seen in the way that the trails diagonally dissect the slopes, intercept and concentrate the runoff, and direct its flow to drainbars or eventual ravines. Because of the steepness of the terrain, the rapid flow carries much soil, which can erode the slopes and expose many plant roots. Likewise, great amounts of organic material are transported from their natural sites to lower elevations. Some of the more outstanding examples are on the upper portions of the Window Trail. Here, the drainbars exceed the trail in width and are frequently taken unintentionally by hikers, resulting in cross-country hiking to return to the trail. With such constant agitation in this more xeric trail section, very few plants are inhabiting the bars, although along their margins *Acacia roemeriana* (Roemer acacia), *A. constricta*, and *Xanthocephalum* spp. are invading. On lower Laguna Meadow Trail the drainbars are dominated by *Xanthocephalum* spp. while along the upper section of the trail, *Artemesia ludoviciana* forms a nearly continuous border; both are unnatural conditions.

Several sampling approaches were used to demonstrate other effects of trails upon the vegetation. The first approach involved two transects sampled across the lower Laguna Meadow Trail approximately 200 and 100 yards north of the Juniper Flat short-cut trail. A line was placed perpendicular to the trail and five contiguous, linear quadrats (10 × 3 ft) were sampled for cover and number of species. Two quadrats occurred above and two below the trail and one encompassed the trail. At these points the trail tread was 8-10 ft wide and located on a western exposure, with a slope of 15-18°. Table 9 presents the IP for each species sampled.

Table 9. Importance percentages of the species in two Laguna Meadow Trail transects.

Species	Above		Trail	Below	
	1	2	3	4	5
Cheilanthes eatoni	4				
Zexmenia brevifolia	5				
Chrysactinea mexicana	11				
Pellea intermedia	18				
Rhus aromatica	33				
Quercus grisea	12	40			
Rhus virens		6			
Cercocarpus montanus		6			
Opuntia engelmannii		7			
Xanthocephalum microcephalum		5	67	69	67
Bouteloua curtipendula	21	34	32	30	22
Acacia constricta					6
Total cover (30 ft^2)	13.3	20.6	5.9	15.5	14.9
Total individuals	15	12	5	7	7
Quercus grisea	5				
Pellea intermedia	5				
Zexmenia brevifolia	7	3			
Artemesia ludoviciana	7	6			
Pinus cembroides	25	42			
Mimosa biuncifera		8			
Bouvardia ternifolia	4			10	
Muhlenbergia emersleyi	4			10	
Viguiera stenoloba	23	13			11
Bouteloua curtipendula	18	28	100	14	17
Rhus virens				10	
Xanthocephalum microcephalum				56	35
Juniperus deppeana					37
Total cover (30 ft^2)	32.7	33.9	.4	11.7	17.6
Total individuals	21	20	3	8	6
Avg. total cover	23.0	27.2	3.1	13.6	16.2
Avg. total individuals	18	16	4	7	6

It is of interest that the average total vegetation cover above the trail approaches twice that below, as well as exceeding this multiple for average total individuals. The species complex above the trail is more diverse with nearly double the species, several being woody plants with woodland affinities. Examples of this are: *Rhus aromatica*, *Cercocarpus montanus*, and the two ferns, *Pellaea intermedia* (creeping cliffbrake) and *Cheilanthes eatoni*. Below both trails the herbaceous, weedy *Xanthocephalum microcephalum* is important, a sign of great disturbance.

A second procedure was used to determine the effect of trails upon tree reproduction. A total census recorded the kind and number of trees and seedlings within 10 ft of both trail margins. To obtain data more sensitive to the impact, the zone was divided into two 5-ft zones of 0-5 ft and 5-10 ft from the trail. These zones were maintained both above and below the trail. A tree was defined as possessing a diameter at breast height (dbh) of 3 inches or greater, whereas any of lesser diameter were classified as seedlings. In the case of multi-trunked *Quercus* spp. and *Juniperus pinchoti*, only one of the upright trunks had to have the prerequisite dbh to be classified as a tree. An attempt was also made to determine and record the generic name of the dead trees within each zone. Only those which appeared near a probable root site were counted in order to avoid mistakenly counting misplaced trees.

A census was taken along the trail from the water-barrel drive to Juniper Flat, on a northern exposure and from 5500 to 5600 ft in elevation. Table 10 indicates that a greater number of trees, living and dead, and seedlings occurred in the less disturbed 5-10 ft zone of the upper side. This is not the case in the below-the-trail census, where the values did not differ significantly.

Reproduction is much greater on the above-trail-side, reaching a near 2 seedlings:1 tree ratio in both zones. On the other hand, the below trail reproduction is less than a 1.5 seedlings:1 tree ratio. As the leading tree, *Pinus cembroides* seems to be the most affected by reduced reproduction, especially below the trail. *Juniperus deppeana* maintains a greater than 2 seedlings:1 tree ratio on both sides of the trail. *Quercus grisea*, *Juniperus pinchoti*, and *J. flaccida* are reproductively poor on both sites. *Quercus emoryi* and *Q. gravesii* are reproducing well, especially on the above trail sites, indicating, along with the presence of *Pinus cembroides* and *Juniperus deppeana* trees, that conditions are more conducive for growth above the trail.

A second census along the more heavily impacted trail from the Campfire Circle to the corral (near Ranger Station) presents different trends. This trail is also on a northern exposure, with an elevation between 5100 and 5300 ft. The distance traversed is about half of that covered by the former census and the sample size about one-fifth. Again, the number of trees and seedlings was greater above the trail, but the difference was not significant (Table 11). No outstanding statement of differences can be made concerning the two zones of the trail sides.

The leading tree, *Pinus cembroides*, again had reduced reproduction especially below the trail. With the exception of *Quercus grisea* and *Prosopis glandulosa*, the reproduction of species is greatest above the trail. The general trend of reproduction is toward more xeric species such as *Quercus grisea*, *Juniperus pinchoti*, and

Prosopis glandulosa, whereas the former census favored the more mesic species *Juniperus deppeana*, *Quercus emoryi*, and *Q. gravesii*.

A census on a new section of trail above Stipa Flat (1967) was made and compared with a similar distance of old trail immediately below (250 paces), with only the above trail side sampled in each case. Table 12 presents the results obtained for two trail sections, the first used for 2-3 years and the other for 10 years. The two sections are extremely similar in species counts, with the major shift being in seedlings. It is of interest that both trees and seedlings are more numerous in the 0-5 ft zone than in the 5- to 10-ft zone. This finding is different from the lower elevational trails sampled. The number of dead trees comprises a much lower percentage of the populations on those trail sections at higher elevations.

Table 10. Tree and seedling census along trail from water barrel to Juniper Flat.

Species	Above trail			Below trail			Grand
	0-5	5-10	Total	0-5	5-10	Total	Total
Trees:							
Pinus cembroides	12	25	37	16	15	31	68
Juniperus deppeana	15	19	34	10	10	20	54
Juniperus flaccida	1	3	4	5	1	6	10
Juniperus pinchoti	5	5	10	2	4	6	16
Quercus grisea	8	11	19	7	6	13	32
Quercus emoryi	—	2	2	—	—	—	2
	41	65	106	40	36	76	182
Seedlings:							
Pinus cembroides	24	41	65	11	15	26	91
Juniperus deppeana	47	35	82	24	17	41	123
Juniperus flaccida	1	1	2	1	2	3	5
Juniperus pinchoti	1	2	3	2	1	3	6
Quercus grisea	6	10	16	8	5	13	29
Quercus emoryi	13	17	30	7	8	15	45
Quercus gravesii	1	6	7	2	1	3	10
Quercus intricata	2	3	5	—	—	—	5
	95	115	210	55	49	104	314
Dead trees:							
Pinus cembroides	4	2	6	2	2	4	10
Juniperus spp.	10	8	18	12	15	27	45
Quercus spp.	23	35	58	10	22	32	90
	37	45	82	24	39	63	145

Table 11. Tree and seedling census along trail from corral to Campfire Creek.

Species	Above trail 0-5	Above trail 5-10	Above trail Total	Below trail 0-5	Below trail 5-10	Below trail Total	Grand Total
Trees:							
Pinus cembroides	7	8	15	5	5	10	25
Juniperus deppeana	1	—	1	—	—	—	1
Juniperus pinchoti	—	1	1	—	—	—	1
Quercus grisea	1	2	3	1	3	4	7
	9	11	20	6	8	14	34
Seedlings:							
Pinus cembroides	2	4	6	—	1	1	7
Juniperus deppeana	3	—	3	1	—	1	4
Juniperus pinchoti	7	1	8	3	3	6	14
Quercus grisea	1	7	8	7	4	11	19
Quercus emoryi	2	2	4	—	1	1	5
Quercus gravesi	—	1	1	—	—	—	1
Prosopis glandulosa	2	2	4	5	3	8	12
	17	17	34	16	12	28	62
Dead trees:							
Pinus cembroides	—	—	—	3	1	4	4
Juniperus spp.	1	3	4	0	3	3	7
Quercus spp.	—	2	2	3	—	3	5
	1	5	6	6	4	10	16

Tree reproduction again exhibits a shift with respect to dominant trees and seedlings on the two previous trail samples. In both sections *Quercus grisea*, *Juniperus deppeana*, and *Pinus cembroides* are dominant trees, whereas none of their seedlings is dominant. The leading seedlings are *Q. emoryi* and *Q. gravesii*, both adapted to mesic conditions, especially the latter. It is interesting that the more xeric *Q. emoryi* is the most common seedling in the lower section. *Quercus grisea* and *J. deppeana* both have reduced reproduction. The success and high number of *Q. emoryi* and *Q. gravesii* are due most probably to the same factors which are at work in Boot Canyon, the primary factor being a shift to a series of more moist years in the climatic cycle. The size of most *Q. gravesii* (3-6 inches) seedlings is similar to the size of those in Boot Canyon. The *Q. emoryi* seedlings are larger (12-30 inches), suggesting an earlier response to the moisture cycle.

A topic relevant to trail ecology and its effect upon the vegetation in the Chisos Mountains is that of horse use and trail maintenance. While I was hiking the various trails to and from areas of concentrated investigation, a syndrome of utmost

Table 12. Comparative census of trees and seedlings along new and old sections of trail.

Species	Lower section			New section			Grand
	0-5	5-10	Total	0-5	5-10	Total	Total
Trees:							
Pinus cembroides	8	3	11	7	2	9	20
Juniperus deppeana	12	1	13	8	7	15	28
Juniperus flaccida	2	4	6	3	1	4	10
Quercus grisea	8	6	14	10	4	14	28
Quercus emoryi	1	—	1	1	—	1	2
Quercus gravesi	3	—	3	1	2	3	6
Arbutus texana	—	—	—	—	1	1	1
	34	14	48	30	17	47	95
Seedlings:							
Pinus cembroides	9	22	31	27	21	48	79
Juniperus deppeana	18	19	37	33	13	46	83
Juniperus flaccida	8	9	17	4	3	7	24
Quercus grisea	9	4	13	13	2	15	28
Quercus emoryi	63	37	100	45	17	62	162
Quercus gravesi	23	16	39	43	17	60	99
	130	107	237	165	73	238	475
Dead trees:							
Pinus cembroides	3	2	5	2	—	2	7
Juniperus spp.	1	—	1	1	1	2	3
Quercus spp.	—	5	5	2	3	5	10
	4	7	11	5	4	9	20

importance to this study of human impact became evident. Although a means of quantifying the problem could not be developed, once the problem was recognized, its ramifications were further observed on many occasions. To consider the problem from its origin is difficult because both horse behavior and trail maintenance practices are involved. The sheer topography and rocky terrain of the mountains are also important factors.

Observations indicate that the horses consistently prefer to use the outer or downslope margin of the trail tread. Several hypotheses could be proposed for such behavior, all of which focus on the fact that the horse selects the smoothest course on the trail. Because of physical factors such as downslope slippage of soil, erosion, and trail site, the smoothest course is on the outer portion of the trail. The trail maintenance philosophy of the National Park Service supports a smooth trail, thus unknowingly making it easier for the horse and more difficult for the trail crew's work in maintaining the trail system.

With continued usage and natural washing, the outer lip of the trail becomes sunken or begins to slip downhill, exposing the underlying rocks. Since the condition is philosophically undesirable, the crew corrects the condition by adding soil. Understandably, since little soil is available to fill the depression, material from the inner margin of the trail tread, which is higher, is picked and raked into the area. The uprooted rocks are pushed over the outer lip to tumble downhill and mar the downslope vegetation. On the many occasions when the trail tread yields too little soil, the bank on the inner trail margin is picked, yielding sufficient soil to fill the outer margins and the rocks are again pushed downhill. The maintenance results in a wider and smoother trail tread until the horses' sharp hoofs and physical factors again expose the more shallow rocks on the inner tread surface and promote the return of soft soils and usage impact to the outer lip, and the horse-maintenance syndrome is perpetuated. Seemingly, the syndrome is a never-ending cycle, leading only to wider and wider trails, higher and higher inner, eroding banks, and longer and longer talus-like slopes downhill. All three conditions contribute to less natural vegetation, but promote more encroachment by disturbed area species. This disturbance is furthered also by the common occurrence of horses treading across natural vegetation at switchbacks.

The condition is not confined to small segments of trail, but can be seen from the basin Ranger Station to Boot Canyon via Juniper Flat or Laguna Meadow, along the main trail to the Lower Basin and the Window trail. A quick glance at an air photo of the more xeric, less wooded Laguna Meadow Trail will show long segments of the trail nearly half as wide as the paved roads. Such wide trails also occur above Juniper Flat, but are obscured by the overtopping woodland vegetation. Although the trail system has been in use for 10-11 years from the Chisos Basin to Boot Canyon via Juniper Flat, and is 29-33 years old from the basin to Laguna Meadow, with significant horse use for only 22 years on the latter sector, the trails and nearby vegetation are already severely damaged. Only time, the amount of future horse use, and types of maintenance practices will be important factors in determining the width of these trails by 2000 A.D., a mere 30 years hence. A major reevaluation of trail use and maintenance must be made in this xeric, steep, rocky environment. Well-defined programs, including maintenance experimentation and well-trained and informed maintenance crews, must be implemented to cope with the natural conditions of the syndrome. Such programs might include motorized wheelbarrows to return rock and soil trapped on drainbars below to areas of maintenance above.

Chisos Remuda concession

The total impact of the Chisos Remuda Concession upon the vegetation is difficult to assess because of the many factors influenced by its operation. One complex aspect was presented in the previous section with respect to the use of horses on trails. Ecologically, the impact is twofold, the effects upon the vegetation by the maintenance of an unnaturally large population of horses in an unusually small environment, and the effects of the horses in performing their services.

The first aspect has many biological implications which must be understood by the management if destruction of the landscape is to be avoided. Because much energy is needed by the horses in performing the service, they require much food. In turn, the side effects of biological refuse in the form of fecal material and urine are great and must be strictly managed if the surrounding environment is not to be affected. Unmanaged refuse amounts to pollution-enrichment of the environment above natural levels by organic and inorganic substances.

Direct evidence of mismanagement of these biological aspects can be readily observed, indicating that concession management has not confronted the problem. Besides the original removal of the vegetation for establishing the concern, the operation has continued to denude the entire flat and western slope of native vegetation. The area is not bare, but is dominated by unnaturally large, introduced populations of *Sorghum halpense*, *Solanum elaeagnifolium*, and *Setaria macrostachya*, none of which is of any importance in the basin under natural conditions. It is by far one of the most unnatural stands of vegetation in the basin. Dissecting the vegetation near the southwest corner of the corral is a large erosional path along which large quantities of feed, manure, and baling wire occur, waiting to be washed to the ravine below. Nearby are the only remnants of the natural vegetation, *Pinus cembroides*, *Quercus* spp., and *Rhus virens*. Under the dense cover of *Solanum elaeagnifolium* and *Sorghum halpense*, *Rivina humilis* (bloodberry) is extremely more common than normal, perhaps due to the increased organic material. At the northwest corner of the corral, an extensive rubbish heap composed of feed, manure, hoof trimmings, and baling wire is washing down the slope to the trail below. In order to determine the immediate extent of the Remuda, the ravine below was followed to near its junction with the Pulliam Ridge drainage. Along the upper third of its course, large dams of manure and feed were found accompanied by clones of *Sorghum halpense*. As a control area, the ravine to the southwest was traversed and no *Sorghum halpense* nor manure or feed were found.

The second aspect of the concession's impact, that of supplying horses for visitor use, relates to trail effects. A biological condition which contributes to impact is the excessive amount of manure and urine which are distributed throughout the basin. The exact effect of these materials is not known, but if the horse service continues, a study should be initiated to determine it. The effect is not always an increased growth of the fertilized vegetation, but may be a decreased growth and/or burning under conditions of overfertilization. The well-known fact that many viable seeds are distributed by fecal matter accounts for the extensive clones of *Sorghum halpense* that appear as one gets progressively closer to the Chisos Remuda and to the tie rack near the Window Pouroff. The odor, large populations of flies, and organically enriched dust, with which the hiker must contend, can all be traced to the extensive impact of the horses. Certainly the effect is not confined to this trail section, but occurs along all trails in the Chisos Basin.

Another form of impact that is due indirectly to the horse is the disregard of the trail bosses for park trail regulations. Special reference is made to their disregard of switchbacks and their encouragement of short-cuts through the native vegetation. Interestingly, this takes place most frequently within view of concession management. The vegetation along the series of switchbacks above the Remuda toward the Upper Basin is much abused and is becoming extremely unnatural in terms of species composition and erosion.

In an attempt to quantify the effect of horses upon natural vegetation, an extensive study was conducted on the sourthern end of Juniper Flat. This area of the flat is used as a short rest site for horseback riders. On two occasions while I was sampling, riders passed through, with one group of approximately 15 stopping for several minutes to break rank for photographing and smoking. The horses scattered over the flat, some grazing the marginal *Stipa tenuissima* and others, the shorter *Bouteloua hirsuta.*

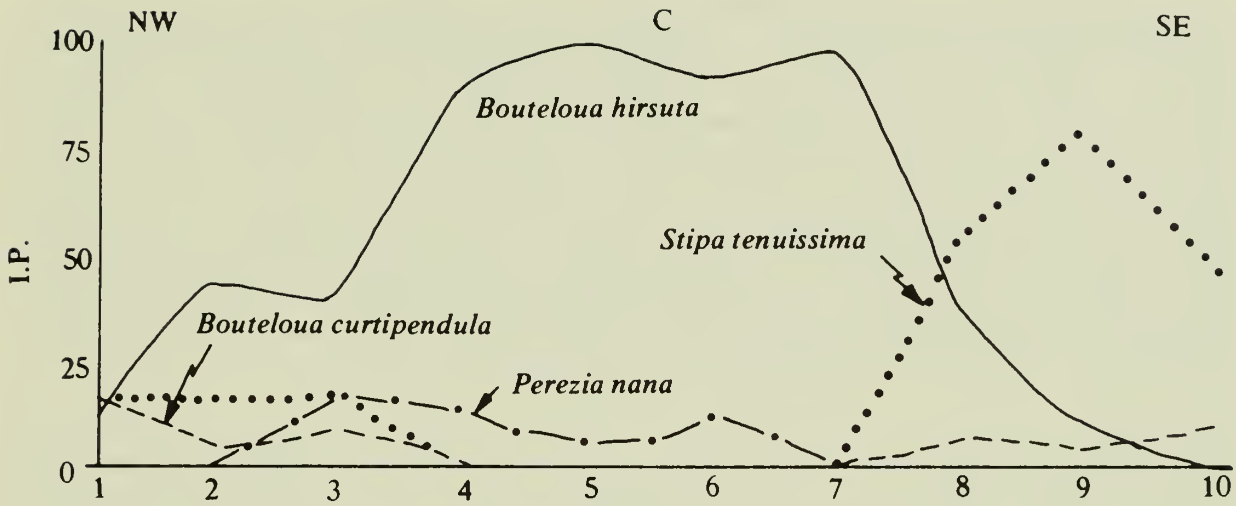
A 200 ft long transect, subdivided into 10-ft sections, spanned from the *S. tenuissima-Juniperus deppeana*-dominated southeast end to the northwest end dominated by *Bouteloua curtipendula-Acacia biuncifera.* Figure 5 presents a summary of the vegetation and soil factors. The IP's of two adjacent quadrants were averaged in order to smooth and reduce the number of points. The soils were collected at the end and center of the transect.

Other species common at the more xeric northwest end (southeast exposure) are *Agave scabra, Nolina erumpens, Aristida divaricata* (poverty threeawn), *Bothriochloa barbinodis,* and *Setaria macrostachya.* The latter two are common in disturbed areas and around the Chisos Remuda. The more mesic end (northwest exposure) are *Pinus cembroides* and *Muhlenbergia emersleyi* at lower importance.

Two soil factors used in this study, but not at other sites, are water infiltration and bulk density. Infiltration was determined by obtaining the time required for 33 cc of water to penetrate the soil. The water was poured into a cylinder 2 3/8 inches in diameter which had been carefully pushed into the soil to a one-half inch depth. A stopwatch was used to record the time for water disappearance for 10 trials at each of the three points along the transect. Bulk density was determined by measuring the volume of soil removed from five small holes, approximately 2 inches in diameter and 1.5 inches deep. The excavated soil was oven-dried, weighed, and weight divided by the measured volume. The volume was determined by pouring measured quantities of sand from a graduated cylinder into the small holes. Both water penetration and the amount of soil per unit volume are functions of soil compaction.

The data on the physical properties of the soil indicate that the center of the flat has less rock and higher infiltration times and bulk density. The latter two factors point to greater soil compaction. The chemical factors reflect the amount of vegetation cover, the lowest values on the center of the flat, and the higher values on the southeast end. Further soil infiltration data were taken on an isolated group of clones of *Stipa tenuissima* near the center of the flat and compared with adjacent bare soil within a 3-ft radius of the group. The 10 values for the protected soil between the clones averaged 33.4 seconds, while that from the bare soil averaged 84.9 seconds.

The results of the study indicate that the present bare portion of the flat dominated by *Bouteloua hirsuta* and *Perezia nana* (desertholly perezia) is not due to



Cover (%)	50	50	20	10	6	6	3	10	45	72

Soil character	NW	C	SE
Infiltration	36.5	89.3	24.5 sec/33 cc
Bulk density	1.28	1.45	1.03 g/cc
Rock	20	6	42 %/weight
Gravel	45	47	37
Sand, Silt, Clay	35	47	21
Sand	73	65	66 %/g
Silt	14	18	18
Clay	13	16	15
pH	7.2	7.1	7.2
Calcium carbonate	7.0	6.0	6.4 %/g
Carbon	0.69	1.05	2.74 %/g
Phosphorus	0.0155	0.244	0.0303 %/g

Fig. 5. Importance Percentage values for Juniper Flat vegetation with respective soil data.

inherent chemical or textural soil qualities, but to physical compaction and removal of the natural vegetation. Compaction of the soil and removal of vegetation create a condition favoring the xerically adapted plants. Another aspect indicating the tendency for growth and reproduction of the natural vegetation is a tree census of the flat. In Table 13 the number of trees and seedlings occurring in the *Stipa tenuissima*-dominated portion of the flat is compared with a portion of the flat dominated by *B. hirsuta*. Since the slopes surrounding the flat were not censused, the *B. hirsuta* area was approximately half the *Stipa tenuissima* area. Conditions seem favorable for reproduction of four species in the more heavily vegetated area and for only one in the impacted portion.

Table 13. Tree and seedling census of Juniper Flat comparing presently grazed and ungrazed portions.

Species	*Stipa tenuissima* (ungrazed)	*Bouteloua hirsuta* (grazed)
Trees:		
Juniperus deppeana	28	1
Pinus cembroides	34	2
Quercus grisea	11	
Juniperus pinchoti	2	
Seedlings:		
Juniperus deppeana	157	3
Pinus cembroides	60	
Juniperus pinchoti	3	
Juniperus flaccida	5	
Dead trees:		
Juniperus deppeana	64	9
Pinus cembroides	6	
Quercus grisea	15	
Juniperus pinchoti	2	

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Initially, this operation had effects on the basin by the removal of the natural vegetation in order to provide space for visitor and personnel housing. After the original removal, the area has remained under constant use and impact, thus providing little opportunity for the remaining vegetation to maintain itself through growth and reproduction. Because of the need to provide an aesthetically pleasing landscape, exotic and other introduced species have been planted. The operation has affected the vegetation indirectly by making great demands upon the water and sewage facilities.

The operation's major effect upon vegetation has been through its gradual encroachment upon the woodland. Unfortunately, the operation is located at the woodland's more critical lower limit which is the area most sensitive to use. The impact has resulted in nearly complete denuding of the woodland area to provide space for the more than 20 buildings which form the complex. These permanent structures and their extensive accesses have contributed significantly to the alteration of natural drainage patterns. Examples can be seen around the lodge, motel, store, and service station. The drainage has been altered to the extent that culverts have been installed to divert lodge drive, motel parking, and personnel quarters' water to the Upper Basin entrance road margin. However, the water is not being directed to its final natural course, which would be the ravine behind the service station and to the area southwest. Even more detrimental to the vegetation are the numerous curbs and walks which prevent even the unnatural flows to assist growth, leaving downfall as the only moisture source.

In conjunction with the decreased moisture from rainfall is the constant impact of man's walking, leaving compacted and denuded sites which are less effective in absorbing rainfall and supporting vegetation. The final results are increased erosion, bare areas, and increased numbers of xerically adapted exotics or introductions. A related factor, the human preference for taking the shortest distance, is overlooked in planning and providing walks which could reduce widespread impact. This is especially evident between the new lodge facility and the store.

The operation, by its unorganized distribution, contributes constantly to the deterioration of the vegetation. This is accomplished either in going from one area to another to perform functions or by damaging the aesthetic qualities of the vegetation in the immediate region, presumably what the operation was established to promote. The latter is questionable when the only replacement plants used in landscaping to alleviate the bareness of removed plants are introduced exotics or plants from the desert. The practice is biologically unsound and wasteful of time and of the introduced species while it also selects against local native species.

An example of introduction is the occurrence of dozens of low elevation, desert cacti inhabiting a man-made planter less than 30 ft from a sheer, badly eroding, desertoid embankment created by construction processes. The cactus, if its pollinators are locally present, could adapt to the new environments and produce offspring, but still would not contribute integrity to the existing local vegetation. The many *Yucca thompsoniana* (Thompson yucca) and *Dasylirion leiophyllum* plantings in the lawn of *Cynodon dactylon*, an exotic around the motel, do not enhance vegetational integrity. The yucca is only native to the desert lowlands and upper slopes of the Dead Horse Mountains in this region. Sotol, however, is common in the lower basin where conditions have been greatly influenced by man's activities, but should it have preference over a pinyon, oak, or juniper removed originally from the site? Because the operation is at the lower limit of the woodland and upper limit of the man-influenced desert, all landscape species should represent the woodland vegetation. *Agave scabra*, *Stipa tenuissima*, and *Nolina erumpens* could lend such integrity for the areas cited above, and there are a number of woodland cacti which could replace the lowland forms presently displayed.

Ranger Station and personnel housing

The Ranger Station and personnel housing facilities required an original denuding to provide space for the structures and accesses to them. Constant human impact around these structures excludes the native vegetation and favors the original denuding process. The impact also encourages the establishment of exotic and introduced species. Both facilities make demands upon water and sewage facilities which indirectly affect the vegetation.

Unfortunately, because of location of the Ranger Station and its accesses, a large area is being affected by human walking, diversion of rainfall, and selected desert plantings. These activities are creating and favoring a xeric condition which is selecting against the natural woodland species, represented here by two struggling *Pinus cembroides* seedlings and several *Agave scabra* plants in the mowed *Cynodon dactylon* lawn. A few other woodland species such as *Juniperus pinchoti, Aloysia lycioides, Andropogon gerardi* (big bluestem), *Bouteloua curtipendula, B. gracilis,* and *Viguiera stenoloba* are behind the station. An incomplete list of the introduced, disturbed area and exotic introductions include *Cenchrus incertus, Eragrostis barrelieri, Tribulus terrestris, Alternanthera peploides, Conyza canadensis* (horsetail conyza), *Setaria macrostachya, Leptochloa dubia* (green sprangletop), *Xanthocephalum microcephalum, Euphorbia strictospora* (slimseed euphorbia), *Panicum obtusum* and others of a more lowland or desert adaptation. A few of these include *Aristida glauca, Machaeranthera pinnatifida, Agave lecheguilla, Acacia constricta,* and *Larrea tridentata.* Several listed are common in the more human-influenced lower basin, but much less common in the woodland formation above the upper basin complex.

The present vegetation in the immediate vicinity of the station could only serve in an interpretational program to demonstrate how man, through his activities, can influence his environment, even to its complete change. The unnatural desertoid area to the east and the unusually dense shrub vegetation to the west demonstrate man's influence. Proper planning, alteration of present drainage, and a natural revegetation program could rectify the situation in time. Such a vigorous program would be applicable around the personnel housing facilities as well. Interested personnel occupying the housing facilities could, through observation and attention, aid in an experimental natural vegetation program, which would benefit the entire impact complex.

Campgrounds

The major effects of the campgrounds are in the maintenance of bare or near-bare areas which provide facilities for the requirements of the camper. Since the camper must circulate through the complex to take advantage of the facilities, impact due to walking and vehicles is inevitable. These activities maintain the desired bare areas and create new sites, increasing the denuding-runoff-erosion cycle. Since campers come from many distant locations, foreign disseminules are introduced into the ecosystem, finding among the many microclimates suitable propagation sites. Facilities such as buildings and roads, by their very existence, decrease the natural vegetation and also increase demands upon water and sewage which have an effect upon the vegetation.

The main campground, the site of major impact, is fortunately confined to a single ridge between two heavily vegetated ravines which restrict approach and impact on the surrounding area. The campground has not altered the natural drainage, but walking and bare areas have increased water runoff into the two ravines. The naturally vegetated areas scattered throughout the campground aid significantly in reducing runoff; however, some natural areas are more densely vegetated because of excess runoff. Runoff and human impact provide great variation in the vegetation.

The main campground provides a variety of campsites, from pleasingly vegetated sites such as 48, 53, 56-59, 62, and 63, to unvegetated sites such as 1-8 and 25. Between these are a range of varying conditions. Isolated between the sites and paved roads are several natural areas such as those between sites 23 and 40, and 15 and 37, which provide pleasing backgrounds. These areas, however, have many unnecessary paths dissecting them which promote erosion and compaction. Large quantities of camping debris litter the areas, impairing vegetation growth and detracting from the aesthetic quality of the natural areas. Landscaped areas, created by the planting of numerous *Cupressus arizonica* (Arizona cypress) trees, promote alien introductions which exclude local native species and unnecessarily change the physiognomy of the vegetation.

In order to determine the extent of human impact upon the main campground vegetation, a survey of all vacated sites was conducted and a transect, 451 ft long and 2 ft wide, was sampled for vegetation cover. The transect spanned from the northwest corner of the concrete canopy base at site 5 to the northeast corner of the first or upper comfort station. From the northwest corner of the station, the transect continued to the southeast corner of the second station. The transect was divided into 10-ft segments and the individuals were sampled for cover. Those areas occupied by paved road were also recorded. At first, an attempt was made to record natural versus impacted bare areas; however, this was abandoned because of the frequently uncertain status of the bare areas. Little of the bare area could be considered natural.

The results of the transect are presented in Table 14. Immediately evident is the low percentage of vegetation cover (34%). None of the 18 sites sampled in the basin had coverage as low; even site 13 in the Chihuahuan Desert Formation had 43%. The value would be lower if the comfort stations and concrete base of the canopy had been included in the transect as impact. It is of interest that the native vegetation was only about 60% of the total vegetation cover. The coverage of exotic species is quite high, indicating the role man plays in altering species composition. With the exception of *Cynodon dactylon* and *Sorghum halpense*, which can cover large areas, the others are relatively small and must be numerous to provide significant cover. The high coverage of *Alternanthera peploides* in the transect was around the moist water hydrants where *Cynodon dactylon*, *Echinochloa crusgalli*, *Bromus unioloides*, and *Sorghum halpense* were also common. It is a natural microclimate for mesically adapted species.

Table 14. Distribution of the cover components of a Main Basin Campground transect.

Paved road cover			110.0[a]	12.1[b]
Bare ground (paths, natural, etc.)			483.0	53.5
Vegetation cover			309.0	34.2
Exotic species cover		29.6[a]		
Cynodon dactylon	18.1[a]			
Salsola kali	6.4			
Sorghum halpense	2.2			
Echinochloa crusgalli	1.8			
Marrubium vulgare	.6			
Bromus unioloides	.3			
Tribulus terrestris	.2			
Weedy native species cover		36.4		
Alternanthera peploides	28.7			
Solanum elaeagnifolium	3.3			
Boerhaavia coccinea	2.7			
Conyza canadensis	1.7			
Disturbed area species cover		51.4		
Bothriochloa barbinodis	14.0			
Chloris virgata	11.7			
Opuntia imbricata	10.4			
Xanthocephalum spp.	7.0			
Prosopis glandulosa	4.0			
Setaria macrostachya	3.1			
Sphaeralcea angustifolia	1.2			
Native species cover		191.6		
Acacia constricta	47.4			
Aloysia lycioides	36.5			
Viguiera stenoloba	21.4			
Bouteloua curtipendula	17.5			
Bouteloua gracilis	15.5			
Opuntia engelmannii	3.2			
Others	50.1			
Total area cover			902.0	

[a]Square feet.
[b]Per cent of total area cover.

Of the total of nine exotic species collected in this study, seven were encountered in this transect. This aptly demonstrates the influence that human impact processes can have upon a vegetation, from the introduction of exotics to the creation of suitable propagation sites for these species. Of special interest is the collection of *Peganum harmala* in the campground. The species was first introduced into the United States in 1938 near Pecos, Tex. (Shinners 1948); by 1955 it was reported near San Antonio, Tex. (Sperry et al. 1963); and now in this study it is reported from the Chisos Basin.

Another aspect pertinent to the ecology of exotic species is the degree to which the vegetation in the southern or upper end of the campground has deteriorated. Normally, in and around clumps of *Opuntia* spp. throughout the southwestern United States, one or several species of native grass clones can be observed. Here, however, it is common to observe *Opuntia engelmannii* harboring large clones of *Sorghum halpense* with or without native grass species. These natural, protected "seedbeds" are promoting exotic rather than native species, and much time and effort will be required to control this condition. In the ravine to the west of the campground behind sites 10, 12, and 21, *Sorghum halpense* and *Solanum elaeagnifolium* is predominate.

The practice of planting introduced species such as *Cupressus arizonica*, *Carya* sp. (hickory), and *Yucca torreyi* (Spanish dagger) falls into a similar category of impact. Table 15 presents a census of the trees and seedlings in the main campground. Over half of the trees are introduced, and most were planted during the expansion program of 1958-59. *Cupressus arizonica*, comprising 37% of all trees, is the most frequently introduced species. Another variety of the species occurs naturally in Boot and Juniper canyons higher in the Chisos Mountains, but is not found locally near the campground. Since the distance is not great for wind-pollinated species, genetic crosses and diseases undesirable to the local population could result from the introduced population. The introduced yuccas are not common at high elevations and lend no integrity to the campground vegetation.

The transect lacked tree species, except for the presence of the introduced *Prosopis glandulosa*. *Cynodon dactylon*, an exotic, is the most common grass, followed by the local dominant, *Bouteloua curtipendula*. The most numerous plants in the natural area between the two upper comfort stations were the locally common shrubs *Acacia constricta* and *Aloysia lycioides*. The most common herb was *Alternanthera peploides*, a native of unnatural importance, followed by *Xanthocephalum microcephalum* and *Salsola kali*, an exotic. Considerable thought and effort must be given to a policy and program concerning these exotic and introduced species which are rapidly reducing native populations as a result of human activity.

The impact of walking was greatest around the comfort stations where the camper can approach from all directions and over any terrain. The south side of the first station demonstrates this damaging effect. Here, the camper from the upper campsites descends a steep, badly eroding slope. In this area *Salsola kali*

Table 15. Tree and seedling census of the Main Basin Campground.

Species		Number of trees	
Total native trees:			47
Total *Juniperus* spp.		10	
Juniperus pinchoti	4		
Juniperus deppeana	4		
Juniperus flaccida	2		
Total *Quercus* spp.		8	
Quercus gravesii	4		
Quercus emoryi	2		
Quercus grisea	2		
Pinus cembroides		26	
Acacia roemeriana		2	
Chilopsis linearis		1	
Total planted trees:			49
Yucca torreyi		11	
Carya sp.		2	
Cupressus arizonica		36	
Grand total			96

was common, accompanied by *Setaria macrostachya* and *Solanum elaeagnifolium*. A similar disturbed and eroding situation occurs around the lower comfort station, especially on its east side. Considerable emphasis must be given to controlling impact around these facilities.

The microclimate created by water hydrants provides a unique habitat for many species, as previously emphasized, and promotes unusual growth in many native species. Because water frequently stands around the hydrants, the microclimate is a constant site for invasion by aliens. Often aiding the cause of the alien is the extremely compacted soil around the site. Adequate drainage should aid in preventing invasion and continued propagation.

A complete survey of nearly all the individual sites revealed lack of vegetation and increasing erosion to be the common maladies. Sites 1-18 and the sites around the second comfort station demonstrate the greatest need for trees, shrubs, and boulders to control the area. Several additional sites had erosional conditions which need control. Sites 47 and 49-52 were the most critical and badly need site-approach control. The area between sites 39 and 42 is in need of stabilization as well as site 42 itself.

Addition of pinyon, oak, and juniper trees would lend integrity to the vegetation, aid in controlling human walking and privacy in the site, prevent erosion, and promote conditions conducive to other woodland species. Care, however, must be taken with their location in order to prevent scorching, as has happened at site 21.

Since *Larrea tridentata* is not common in the area and those in the campground are situated on roadbed material from lower elevations, these individuals should be removed to prevent further invasion and seed dispersal. This species is occupying potential woodland species sites and producing large quantities of seeds which can invade the numerous eroded areas. Individuals can be found around sites 23, 49, 43, and 60. Some are also found along the road leading to the group campground and in the Campfire Circle parking area.

Sewage

The effect of sewage upon basin vegetation is twofold in nature: both the raw sewage and the sewage lagoons themselves affect the vegetation. Basically, the control of sewage necessitates the creation of denuded areas to contain the materials. By this action the area remains open to erosion and to constant invasion by disturbed-area species. Because the materials are in an aqueous condition and high in organic matter, rich, moist habitats are provided.

The effect of raw sewage upon the vegetation is very apparent to the southwest of the Trailhead in the Upper Basin below the Ranger Station. Here, a sewer cover provides escape of the raw material onto the natural vegetation. I first became aware of this action in 1964, while observing a large flowering clone of *Agave chisoensis* (Chisos agave) nearby. At that time the vegetation was dominated by *Viguiera stenoloba*, *Xanthocephalum* spp., and *Acacia constricta*. Since that time the vegetation has become more dense to the southwest where the major flow drains. In the last two years the spillage has greatly increased to the extent that it has killed many *Viguiera stenoloba* and *Xanthocephalum* spp., which can be observed in the area. Also the area is difficult to approach because of the increased soil moisture.

The effects of the sewage lagoons are numerous, the most direct being the support of large numbers of adventive desert species, disturbed-area species, and exotics. The most common desert plants collected along the eroding slopes of the lagoons were *Erioneuron pulchellum*, *Baccharis glutinosa* (seepwillow baccharis), *Machaeranthera pinnatifida*, *Croton pottsii* (leatherweed croton), *Porophyllum scoparium* (poreleaf), *Sphaeralcea angustifolia*, *Senecio longilobus* (threadleaf groundsel), *Digitaria californica* (Arizona cottontop), and *Baileya multiradiata*. Also collected or observed along the water margin were the exotics *Echinochloa crusgalli*, *Sorghum halpense*, and *Tamarix pentandra* (tamarisk) or *T. gallica* (saltcedar). The tall *Tamarix* individual was dead and difficult to identify by bark characteristics.

Along the water margin of the eroding banks, *Echinochloa crusgalli*, *Conyza canadensis*, *Chloris virgata* (showy chloris), *Digitaria californica*, and *Setaria macrostachya* are dominant. The prostrate *Boerhaavia coccinea* (scarlet spiderling) contributes significantly to ground cover and erosion control around the upper lagoon. *Clematis drummondi* (Texas virgins bower) covers extensive areas around the lower lagoon in a similar manner. On the upper, more exposed, eroding slopes, *Baccharis glutinosa* is most common. A few *Salix* sp. (willow) are becoming established on the lower lagoon. They were not specifically identified because of their lack of leaves and small size in August. Between the two lagoons a remnant of native vegetation is progressing adequately. It consists of *Acacia constricta*, *A. roemeriana*, *Aloysia lycioides*, *Rhus microphylla* (littleleaf sumac), *Opuntia engelmannii*, *Diospyrus texana* (Texas persimmon), and *Bouteloua curtipendula*.

Other effects of the lagoons upon the vegetation are the infrequent overflow and seepage through the bank, aiding in the establishment of a variety of species at these sites. Also there are algal blooms which could cause death to wildlife visiting the lagoons. While working around the lagoons, the author observed two white-tailed deer within the fence and one dead deer. The cause of death could not be determined; however, an algal bloom was present at the time. The death could have been due to the animal crashing against the fence attempting to escape, as such behavior was observed on two occasions. It was later reported by Chief Naturalist Roland Wauer that other deer had been found dead within this enclosure. If these deaths continue and the effects are not traced to the sewage or algal blooms, the fence should be removed or heightened as policy dictates. The deaths are not significant in number, but the carrion-oriented food chain could be affected.

Pipelines

Pipelines have had three major ecological effects upon the vegetation. The first is the denuding effect required to lay the line; second, the effect of the disturbance upon the soil and revegetation sequence; and third, the erosion paths which can develop because of vegetation reduction. The revegetation sequence has been important in determining local species dynamics and the time required for revegetation. This topic was discussed at the beginning of this section.

Those lines constructed in the Chisos Basin have had all of the above effects. The most extensive line is the water line laid in 1952 from the Window to the water barrel above the Upper Basin complex. The scar is visible for its entire length due to the altered rock and soil strata and the disturbed-area species dominating the scar. The species present are primarily grasses: *Bouteloua curtipendula*, *Aristida glauca*, *Heteropogon contortus*, and *Bothriochloa barbinodis*. Infrequently, *Bouteloua breviseta* and *Panicum hallii* (Halls panicum) are present. A few herbs and shrubs are beginning to invade the scar: *Dasylirion leiophyllum*, *Mimosa biuncifera*, *Opuntia engelmannii*, *Viguiera stenoloba*, and *Croton pottsii*.

Other less extensive lines can be observed in the basin. A short line north of the ranger personnel homes is recent (1962-64) and is dominated by *Eragrostis intermedia*, a disturbed-area species. No other significant species of invader is found here. In a small, year-old scar below the Ranger Station, a sizeable list of invading species was made including *Leptochloa dubia*, *Bothriochloa barbinodis*, *Sphaeralcea angustifolia*, *Setaria macrostachya*, *Panicum obtusum*, *Euphorbia strictospora*, and *Ximenesia encelioides* (golden crownbeard).

A heavily impacted pipeline scar at the southwest corner of the main campground presents a situation similar to that of the old road scar previously discussed. In this scar many of the species are of low elevation origin, suggesting desert origin of the lighter-colored, gravelly soil. Species include *Larrea tridentata*, *Erioneuron pulchellum*, *Polygala scoparioides* (broom milkwort), *Xanthocephalum sarothrae* (broom snakeweed), *Machaeranthera pinnatifida*, *Marrubium vulgare*, and *Sporobolus cryptandrus*. Because of the continued impact of the Window Trail dissecting the scar, these species continue to be promoted. A second heavily impacted and eroding scar lies below the lower portion of the main campground and terminates at the pumphouse below. In this disturbed scar *Polygala alba* (white milkwort) and *Aristida glauca* are common. This scar must have immediate attention to prevent irreparable damage to the landscape. In no instance should the soil used in such repair be obtained from lower elevations. Any common local shrubs and soil from the eroding bank opposite the pumphouse could be used in stabilization.

Wells

The effect upon the vegetation of the two wells drilled in the basin is difficult to assess. The first well, drilled in 1934, permitted and supported all the activities in the basin until the present Oak Springs water source replaced it in 1952. Several of the facilities initially supported by this first well are still present and still having effect upon the basin vegetation. No direct evidence of effect upon the vegetation other than the road to the well, the pumphouse, and erosion accompanying both can be cited. The margins of the road are in immediate need of stabilization.

The second well, above the present National Park Concessions warehouse, was drilled and abandoned in 1947. The direct effects are still evident around the denuded, eroding site where concrete abutments persist. Perhaps the greatest effect of this project is the steep trail leading to the well site. This trail needs stabilization or, preferably, complete abandonment with controlled planting.

The effect the wells had upon the basin water table, which would affect the vegetation, is not known. This could have been especially serious during the early drought years, when the only major natural spring, Kibbey Spring, ceased its normal flow. That the spring still has only intermittent flow could be due to the previous history of grazing and use of the spring by the animals.

8

Future Vegetation on the Basin

The vegetation of the Chisos Basin in the future will show a shift in dominance in several areas, provided prevailing conditions continue to support the present trees and seedlings. Present evidence suggests that, above the Upper Basin complex, conditions are favoring the more mesic species, whereas in the impacted areas the more xeric species are favored.

A total census taken along the trail from Juniper Flat to the Laguna Meadow Trail is presented in Table 16. The census was taken in the manner described previously under trail impact. The *Quercus grisea-Pinus cembroides* tree-dominated trailside is shifting to a possible *Q. emoryi-Juniperus deppeana* vegetation type. This infrequently used trail is on a western exposure; the lower end is more southern and the upper portion more northern. The numerous *Q. gravesii* seedlings censused are significant as they are the most mesically adapted species listed.

The census of the circle at Boulder Meadow, at a higher elevation, presents a different dynamic pattern (Table 17). The importance of this census is the significant number of *Juniperus flaccida* and *J. deppeana*. This site gives the highest reproductive ratio, 1 tree:13 seedlings, of any area censused in the basin. A similar ratio for the previous trail sector was 1 tree:7 seedlings, a rather high value. A similar value for the impacted areas of the basin is less than 1:2.

The results of a series of censuses taken in the Upper Basin region are presented in Table 18. A raw comparison between the areas is not valid, but a comparison with percentages and within an area is significant. The total census presents the trend for the area from the stone cottages to the Campfire Circle, with emphasis upon the mesic northern exposure. The large number of *Prosopis glandulosa* seedlings is of interest for this species is a "weedy" introduction. All sites favor the xeric species, *Juniperus pinchoti* and *Quercus grisea*, as their tree-to-seedling reproductive ratios are greater. Every area had less *Pinus cembroides* seedlings than trees.

The outlook for tree reproduction is good for those areas not presently under severe impact. This impact, as demonstrated by Table 18, need not be more than a trail dissecting the slope or area. The flat area (3), below the Ranger Station, no longer has heavy impact and shows the greatest tree-to-seedling ratio, 1:3. Included in those areas under impact would be the vegetation directly below the miles of basin trails, which show a decreased reproductive rate. This, I believe, results from falling rock and soil along with disrupted natural drainage patterns by the trails. If the trails continue to deteriorate, the condition will become more severe with time. These areas are now more open, thus more xeric, during a time when the major vegetation conditions are favoring the more mesic species.

Table 16. Tree and seedling census along trail from Juniper Flat to Laguna Meadow Trail.

Species	Above trail			Below trail			Grand
	0-5	5-10	Total	0-5	5-10	Total	Total
Trees:							
Pinus cembroides	12	8	20	6	8	14	34
Juniperus deppeana	7	3	10	6	5	11	21
Juniperus flaccida		3	3				3
Juniperus pinchoti				1		1	1
Quercus grisea	8	16	24	4	9	13	37
Quercus emoryi	2	5	7	1		1	8
Quercus gravesii				1	1	2	2
	29	35	64	19	23	42	106
Seedlings:							
Pinus cembroides	22	18	40	14	8	22	62
Juniperus deppeana	68	50	118	54	46	100	218
Juniperus flaccida	3	5	8	11	5	16	24
Juniperus pinchoti	1		1	1		1	2
Quercus grisea	72	50	122	25	42	67	189
Quercus emoryi	81	58	139	58	29	87	226
Quercus gravesii	21	15	36	6	11	17	53
Prosopis glandulosa	2		2				2
	270	196	466	169	141	310	776
Dead trees:							
Pinus cembroides		2	2	3	1	4	6
Juniperus spp.	3		3	4	3	7	10
Quercus spp.	9	15	24	11	3	14	38
	12	17	29	18	7	25	54

Table 17. Tree and seedling census along trail in circle at Boulder Meadow.

Species	Within circle 0-5	5-10	Total
Trees:			
Pinus cembroides	2	4	6
Juniperus deppeana	6	6	12
Juniperus flaccida		1	1
Quercus grisea	2	1	3
Quercus emoryi		1	1
Quercus gravesi		1	1
	10	14	24
Seedlings:			
Pinus cembroides	15	48	63
Juniperus deppeana	41	51	92
Juniperus flaccida	27	19	46
Quercus grisea	2	1	3
	85	119	204
Dead trees:			
Pinus cembroides		2	2
Juniperus spp.	3	2	5
Quercus spp.	1	2	3
	4	6	10

Table 18. Tree and seedling census of several areas in the Chisos Basin.

Species	Locations[a]						Total
	1	2	3	4	5	6	
Trees:							
Pinus cembroides	100	74	16	17	45	7	260
Juniperus deppeana	59	4	7	3	7	2	82
Juniperus flaccida	15	3	3	3	2		26
Juniperus pinchoti	4	8	4	1	1	4	22
Quercus grisea	9	21	3	6	8	8	55
Quercus emoryi	5		2	1		1	9
	193	110	35	31	63	22	454
Seedlings:							
Pinus cembroides	58	37	13	7	15	3	133
Juniperus deppeana	50	17	13	4	3	4	91
Juniperus flaccida	4	12	3	1	4		24
Juniperus pinchoti	11	30	38	8	12	3	102
Quercus grisea	11	38	14	5	8	12	88
Quercus emoryi	9	13	1	1			24
Quercus gravesii		1					1
Prosopis glandulosa		16	27	3	6	5	57
	143	164	109	29	48	27	520
Dead trees:							
Pinus cembroides	9	13	4	5	1	11	43
Juniperus spp.	25	13	13	22	17	13	103
Quercus spp.	31	25	13	1	1	9	80
	65	51	30	28	19	33	226

[a] 1 North exposure of ravine east of stone cottages.
2 North exposure of ravine from Campfire Circle to Ranger Station.
3 Large flat to the west of the corral near Ranger Station.
4 Circle of Window view hill.
5 North exposure of the Window view hill to trail below.
6 South exposure of the Window view hill to ravine below.

9

Basin Impact Upon Oak Creek Canyon and Cattail Falls

The effect of Chisos Basin activity on these two areas is extremely difficult to assess. The basin makes demands upon both for water and also has impact upon Oak Creek Canyon from above, since the total of all basin runoff water enters Oak Creek Canyon. This runoff contains large amounts of soil, rock, introduced and exotic plants and seeds, organic material from horses, and camping-hiking debris. This can be readily observed below the pouroff where large quantities of rock, clones of *Sorghum halpense*, paper, and cans are found. Fortunately, the clones of *S. halpense* fail to survive further down the wash, although many survived long enough to flower.

No immediate effects were apparent to indicate that water usage from Oak Springs was having an adverse influence upon the vegetation; however, large cottonwood trees were found dead in the streambed around and above the water barrel. Since no comparative information is available, impact cannot be definitely assessed. It is of interest that Casey (1968) indicates that Oak Springs was constantly flowing and that vegetables and fruits were productively raised along the watercourse. The large cottonwoods and oaks at the Cattail Falls parking area would certainly suggest such conditions. A comprehensive study of the vegetation along the ravine, with supporting evidence from growth-ring comparisons of shrubs and trees, could provide more accurate information.

Since Cattail Falls drainage is from the upper slopes of Ward Mountain, basin activities do not affect the falls' microclimate. The pool of the small canyon has become smaller and more shallow since 1964 due to increased quantities of gravel and silt. The increased vegetation around the pool may be preventing the movement of silt and rocks downstream, thus building a larger bar which becomes compacted by walking and eventually is vegetated.

Again, no immediate effect due to reduced water could be detected; however, a similar study of vegetation and growth-ring analyses could provide an approach. This study should include work on Cottonwood Wash and immediate springs in the area such as Gano Springs, where many dead cottonwoods can be observed.

10
Summary and Conclusions

Although the first record of man in the Chisos Mountains was in 1747, his influence upon the land was not significant until the cattlemen arrived in the 1880s. From this time until the establishment of Big Bend National Park in 1944, the vegetation which supported man's livestock was visibly changed by overgrazing. In 1934 the Civilian Conservation Corps established the first road which facilitated living in the remote Chisos Basin. These early activities provided the impetus needed to expand the facilities to their present status. During the major National Park Service developmental phase of the 1950s, the basin experienced the most severe drought recorded in the mountains. The earlier effects of grazing were amplified by the drought and the vegetation is only presently exhibiting significant signs of recovery.

The basin is an elevated bowl, carved by erosion from layers of Cenozoic lava and intrusive ridges. The resulting steep, rugged topography presents complex patterns of parent material from which the soils are derived. The soils have no particular pattern of distribution and belong to three classes: sandy loam, sandy clay, and sandy clay loam. Three vegetation formations are supported by the soils: Evergreen Woodland Formation, Chaparral Formation, and the Chihuahuan Desert Formation. The chemical characteristics of the soils supporting the formations exhibit certain general trends. The pH increases with aridity as does calcium carbonate; however, carbon and phosphorus decrease in amount from chaparral to woodland to desert, respectively.

A long-range climate analysis indicates a combined warming and drying trend; however, the character of the basin vegetation presently exhibits a shift from a short, xeric cycle to a more moist and cool period. The adjusted annual rainfall of 18.26 inches occurs primarily in the months of May through October when the daily maximum means are approximately 68-88°F. Only rarely does the low winter moisture come in the form of snow and sleet.

The present basin vegetation, although complex in composition and distribution, can be categorized into three major physiognomic-physiographic types: a tree-dominated, northern exposure, upper elevation, Evergreen Woodland Formation; a shrub-dominated Chaparral; and a southern exposure, lower elevation, semisucculent-dominated Chihuahuan Desert Formation. The major woodland trees in increasing dominance with elevation are; *Juniperus pinchoti*, *Quercus grisea*, *Pinus cembroides*, *J. deppeana*, *Q. emoryi*, *J. flaccida*, and *Q. gravesii*. Shrubs and grasses can be locally dominant as well as succulents and herbs to complete the three woodland strata. The desert formation, dominated by the semisucculents *Agave lecheguilla* and *Dasylirion leiophyllum* and succulent *Opuntia engelmannii*, is confined to two strata. *Acacia constricta*, *Viguiera stenoloba*, and *Fraxinus greggi* provide the upper stratum, while locally dominant grasses such as *Bouteloua curtipendula*, *B. hirsuta*, *B. eriopoda*, and *Aristida glauca* control the lower stratum. The latter two formations have many similar features; however, in the chaparral succulence is relatively insignificant.

Vegetation dynamics suggests that the woodland is expanding toward its pregrazing range status. The process is slowed because the majority of human activity is centered at the formation's lower contact with the man-influenced desert. The woodland species must also compete with the numerous desert and disturbed-area species which responded to the impact conditions and control the region. Many of these species have long lifespans and can occupy the area for considerable time.

Investigations on the present forms of impact indicate that both the vegetation and physical factors of the environment have been altered by the activities of man. The major alterations observed in the vegetation are decreased numbers of natural individuals, decreased numbers of natural species, decreased natural cover, decreased community complexity, and decreased community stability. All of these characteristics are attributes of the disturbed area, unstable due to environmental changes. The severity of the change determines the degree of the exhibited effects. The forms of present impact ranged from totally denuded areas, such as around buildings and along trails, to densely vegetated areas with impaired drainage.

The forms of environmental change most severely affecting the vegetation were the alterations of drainage patterns and disturbances of the soil by upheaval or denuding, which result in the alteration of many soil factors. Since the soil factors and vegetation are reciprocally interrelated, the alteration of the vegetation acts also as an environmental change. The most frequently observed altered soil factors were increased compaction, increased runoff, decreased infiltration, and altered soil strata. These changes influence soil moisture, temperature, gas exchange, microorganisms, pH, nutrients, and stability, all factors which influence the vegetation.

The following actions upon the vegetation by man were observed or sampled in the impacted areas of the basin. They are drawn from the above interrelationships between the vegetation and its environment.

Denudation

The areas of man's activity have been denuded, initiating a complex natural sequence of factors and plant species. The denuding process favors only a few species in the basin (Table 7) which are adapted for survival in the area. These species are generally herbaceous in the earlier stages and have high physiological tolerances for low moisture, necessitate low nutrients, provide numerous disseminules, and are represented in the later successional stages by long-lived shrubs.

Many years are required for the succeeding vegetation to provide adequate conditions for native vegetation to regain dominance. Evidence indicates that from 25 to 50 years are required for reestablishment of the Chihuahuan Desert Formation in the basin, and 75-100 years for the Evergreen Woodland Formation. All too frequently the succession is halted in the initial stages and seldom advances, thus favoring xeric species.

Examples of this impact, roughly in the order of decreasing contributions to basin denuding are: roads and parkings, trails, National Park Concessions, Ranger Station and personnel housing, sewage facilities, pipelines, campgrounds, Chisos Remuda, Campfire Circle, and wells.

Alteration

Man, by constructing service facilities in the basin, has altered the terrain and the natural drainage patterns. This impaired flow causes excess moisture and eroded soil to occupy the area, resulting in dense vegetation which occurs below the Ranger Station. The structures may also divert the flow so that little runoff reaches the site, as occurs in the desertoid area on the east side of the Ranger Station.

The major promoters of impairment action are roads and parkings, trails, and National Park Concessions buildings and their access walks. Not only do the roads and parking areas in their construction alter the drainage, but thereafter their hard, undulating surfaces influence runoff. The numerous eroding road-cuts demonstrate the undesirable consequences that can result. By dissecting the steep slopes and crossing the numerous ravines, the trail system also functions as an unnatural runoff diversion. The heavily silted drainbars, which increase in size with each downpour, demonstrate trail interception of runoff. Each of these alterations significantly influences the vegetation.

Creation

The activities of man have created many new, disturbed habitats in the basin which exclude the natural vegetation and promote the creation of new vegetation types. An outstanding example is the disturbed vegetation type to the northeast of the main campground, created by man's livestock. At least seven new habitats were created in the main campground that support the exotic species (Table 14), along with the many "weedy" species habitats. All newly created areas and their vegetation detract from the integrity of the regional landscape. Few of man's activities have created suitable habitats for the native woodland trees and shrubs, since most sites are highly compacted or in a state of erosion.

Introduction

Man has played an important role in the introduction of new plant species into the basin, as is evident in his impacted activity areas. In this study alone nine exotic species were collected in the Upper and Lower Basin complexes, even though no special attempt was made to include them in sampling. Introduced "weedy" native species are also evidence of man's activities. The establishment of new species has been promoted by the introduction and frequent use of desert soils in basin construction and maintenance. This practice not only introduces numerous species but also provides them with the native soil most conducive to their growth. Frequently, the species are able to invade other habitats and extend their influence.

The ability of these species to succeed is evident, and methods to control them in the basin should be developed and employed. The special man-provided habitats which promote them must be alleviated and suspected methods of introduction eradicated or reduced. The major avenues of introduction in the basin are the Chisos Remuda, visitors in the main campground and National Park Concessions facilities, and the National Park Service in its transport of soils for road maintenance and construction programs. The source of *Sorghum halpense* and *Solanum elaeagnifolium* can probably be traced to the feed or fecal matter of the horses fed outside the basin prior to their entrance. The frequency and density of both species increase greatly as one approaches the operation from all directions, especially along the road leading to the Remuda and around the stables. The seeds are further disseminated as the animals traverse the mountains.

The campgrounds and National Park Concessions harbor the greatest variety of exotic species, reflecting the numerous distant origins of the visitors and the conditions conducive to growth offered by the many diverse habitats in the areas these visitors frequent in the basin. A considerable stand of *Sorghum halpense* is present in the moist ravine to the north of National Park Concessions warehouse.

Pollution

Man's activities have polluted the Chisos Basin and have affected the vegetation. The effect of added organic material in the form of raw sewage and fecal matter of animals can be observed. The effects of raw sewage are presently localized to the Upper Basin near the Trailhead and infrequent seepage from the lower lagoon. The action of this pollutant has caused death to some plants, while increasing growth of others. The unnatural, large populations of animals at the Chisos Remuda have significantly altered the vegetation by their pollution. The total effect of pollution by horses cannot be readily determined, but cognizance of the condition may eventually lead to the measurement of more effects. A similar condition exists in the attempt to assess the pollution due to service station spillage, automobile effects, and the gallons of cooking grease and waste water poured into the campsite vegetation in the campgrounds. Since the latter are imparting a distinctive odor to the campgrounds, they have residual effects.

Destruction

All the above actions are taking place in the basin, and without altered programs the activities of man will continue to perpetuate the impact. Unfortunately, man's demands upon this unique basin are increasing exponentially, as are his effects upon the landscape. As the major factors which influence the vegetation are known, programs to curtail the actions can and should be initiated to reverse the effects of impact.

If the basin vegetation is to continue its struggle to recover from the grazing and drought years and to regain any semblance of integrity from present impact, every effort must be made to curtail activities in the basin. All present activities should be evaluated to determine if they are absolutely necessary or desirable. Many of the observed activities could be performed equally as well at lower elevations, thereby reducing impact upon the unique, less stable landscape of the basin. The order of priority for immediate evaluation based upon present vegetation impact is: National Park Concessions, Chisos Remuda Concessions, National Park Service personnel housing and Ranger Station, and trails, roads, sewage, and campgrounds.

To assist the revegetation cycle in impacted areas and those closed to use, a vigorous program of rehabilitation should immediately be initiated. The revegetation program should at all times be biologically sound and in accord with the natural revegetation cycle of the basin. To aid rapid recovery, all species used in the program should promote the mesic woodland species, as the native desert vegetation and exotic species will prevail by default of the woodland vegetation's inability to become established initially.

11

Recommendations

Basin

The major recommendations for the Chisos Basin are directed toward preventive control of impact and rehabilitation for those areas already impacted. Since the major form of activity centers around exposing the visitor to the unique landscape, effort must be made to provide this service in the smallest area possible and with the least effect upon the vegetation. Definitely, no further plans should be considered which will expand the impacted areas. Instead, a vigorous rehabilitative, revegetative program should be instituted to provide a more natural vegetation in both the Upper and Lower Basin complexes.

Since there is presently no Mountain Woodland Interpretive Program, one should be provided to offer a broader educational opportunity to the visitor. With the suggested reduction of visitor lodging and personnel housing in the Upper Basin, the present Ranger Station location would provide an excellent site for an interpretive center with a panoramic view of the basin and with close access to the woodland. From this center the visitor would have easy access to dining, auto, and food supplies, not to disregard Ranger Station services and easy access to several potential self-guided nature trails of varying lengths.

It is highly recommended that a program be instituted to phase out the use of horses on all basin trails. This unnatural population is creating or contributing to every major form of vegetation impact which was investigated. The decay of the trail system and the spread of *Sorghum halpense* are definitely attributable to their activity. One cannot expect to maintain any near-natural form of vegetation along the trails in the basin if the use of horses is permitted to continue.

Accompanying the vigorous rehabilitative-revegetation program, human walking and exotic or introduced species must be controlled. With a program to eliminate mountain lodging and unnatural horse populations, the only remaining areas of concern would be the campgrounds. Because the campgrounds are confined to more isolated areas, their effect is more restricted than the other two, hence walking and alien introductions can be more readily controlled.

Basic rehabilitative revegetation program

This program should be initiated as soon as the groundwork can be laid. The immediate plan should take advantage of the climatic cycle which is presently supporting significant reproductive advancement of the woodland trees. The program will probably require 15-20 years to shift the present man-influenced xeric condition to the native woodland vegetation. The major emphasis should be directed toward all impacted areas of the Upper and Lower Basin complexes. The area between the complexes should also be given attention, especially along those slopes with trails. The more extensive erosion sites along the roadcuts and trails should also receive attention, as well as abandoned impact areas.

The program should be under the direction of a Park Biologist who has ecological training and contact with consulting plant ecologists, soil geologists, and other pertinent consultants with extensive experience in regional woodland dynamics. Records of all procedures and plantings should be maintained for periodic evaluation and future reference. In the early phase of the program, moisture supplementation may be required for the trees and shrubs; however, as the program progresses natural vegetation will become established and supplements will not be required.

The basic program would entail the following steps: (1) The preparation of the bare or impacted site for vegetation establishment by controlling human walking, providing near-natural runoff moisture, adding sufficient rocks to slow runoff, and providing large, temporary rocks which can cast shade on newly established seedlings during the summer months, etc. (2) An annual collection of *Bouteloua curtipendula* fruits should be made in the basin along the pipeline scars, etc., to sow in the prepared impacted areas. This planting should be done 2 or 3 years in advance of the woody plantings to aid in site stabilization. (3) An annual surveillance should be made of the basin for sites of extraordinary Evergreen Woodland Formation species reproduction from which seeds, cuttings, and small seedlings for transplanting may be taken. The biologist and consultant should make this evaluation to prevent excess removal from the source. An example of an area which exhibits high reproduction presently is the northern end of the Boulder Meadow circle (Table 17). (4) To ensure success of the program, the seeds, cuttings, and seedlings should be propagated in a temporary starting nursery established in the area around the water barrel. Here the many plants can be furnished water to promote more rapid and controlled growth and ensure establishment when transferred to the rehabilitation site. Once a sufficient supply of plants is provided, the nursery can be phased out with no undue impact to this area and in the process it can rehabilitate the area around the water barrel. Most of the shrubs can be propagated from cuttings rooted in auxin-supplied solutions and soil culture.

The suggested trees for planting are *Pinus cembroides*, *Juniperus deppeana*, *Quercus grisea*, and *Q. emoryi*. Suggested shrubs are *Rhus virens*, *R.aromatica*, *Garrya lindheimeri*, *Cercocarpus montanus*, and *Ceanothus greggi* (desert ceanothus). *Nolina erumpens* and *Agave scabra* are suggested succulents; however, *Dasylirion leiophyllum* could be judiciously used as a supplement. Grasses which could be planted after the *Bouteloua curtipendula* stabilization period are *Muhlenbergia emersleyi*, *Piptochaetium fimbriatum*, and *Stipa* spp. (needlegrass). These should be transplanted as clones and supplemented by the sowing of fruit.

Exotic and introduced species program

The emphasis of this program should be to control and eventually eradicate all exotic and introduced species from the Chisos Basin, especially in the man-influenced areas. A second aspect of the program should be to alleviate all sites which support such populations. These are frequently erosion sites along roads and trails and moist areas around water hydrants. The third area of concentration should be to control or alleviate the means of introduction. Since several of these are directly related to National Park Service, Chisos Remuda, and National Park Concessions maintenance and operation, this can be quite readily controlled.

Presently, there are several introduced populations which should be removed from the basin. The *Cupressus arizonica* trees in the main campground and Campfire Circle should be replaced with native trees and shrubs listed in the basic revegetation program. The cypress trees are not native and falsify the vegetation at the expense of native trees. Since *Larrea tridentata* is not a common natural species in the Lower Basin, all plants in the campground, along the Lower and Upper Basin roads, should be removed. Those which occur in the transported soils of the old road scar and pipeline scar should also be removed. They all produce great numbers of seeds which may find suitable germination sites and dominate the unnatural area for many years. If the increase of *Prosopis glandulosa* continues, a program controlling this species should also be considered.

A policy and sound program of exotic species control and removal should be instituted, especially of those listed in the study. The most important is *Sorghum halpense*, found commonly along the roads, in the campgrounds, and around the Chisos Remuda in the Lower Basin. Other exotic species are found locally distributed in eroded areas and around water hydrants in the compground. These can be quite easily controlled by removal. A long-range program should be adopted to rid the basin of the man-supported lawns of *Cynodon dactylon*. A gradual transplanting of natural grasses into the lawns from the basic list are suggested. Since the native species are clonal grasses rather than carpet-forming in nature, they will not become as dense and will be much slower to develop.

Chisos Remuda

The major corrective measure taken by the National Park Service toward this impact force should be the total removal of Chisos Remuda from the Chisos Mountains. The basin is too small and unstable in terrain, climate, and vegetation to support the constant impact of the unnatural population of horses. The effects of the horses are so widespread that the total ramification cannot even be delineated in terms of direct effects upon the vegetation. Attempts to identify them for future investigators are scattered throughout this text. The most serious effects are upon the trail system, which is unstable, poorly maintained, poorly constructed in some areas, and directly alters the vegetation. The terrain itself contributes significantly to these poor conditions. The few park visitors who benefit from the service do not justify the irreparable damage to the vegetation, increased trail maintenance costs, and the intolerable conditions which the hiker must endure because of the fecal material and dust.

In the event the program cannot be phased out, a vigorous unified program by both the National Park Service and Chisos Remuda management must be undertaken to rehabilitate the impacted area around the operation. The rehabilitation program must be directed toward the halting of pollution around the corral. All present and future waste should be removed from the basin, and especially the present refuse dump near the northwest corner of the corral. A barrier system should be constructed around the corral to retrieve all the large particles, preventing their entrance into the surrounding ravine systems. The possibilities of a water filtration system to purify the runoff water from the corral should be investigated for feasibility. All baling wire and other by-products should be properly disposed of in containers for removal from the basin.

The area around the concession should undergo the general rehabilitation-revegetation program. Immediate attention should be given to the areas around the corral and to the west slope in particular. Efforts to reduce the spread of exotics and to disseminate viable seeds through feed should accompany the revegetation program.

Under the leadership of the National Park Service, a trail-respect program for the trail bosses should be initiated. The program should include interviewing the incoming trail bosses to disseminate National Park Service philosophy and information concerning the problems of trail maintenance that are related to their duties. The program could also introduce personnel to the plants, animals, history, geology, and ecology of the mountains and park. A trail-abuse fine system for off-trail walking, directed toward both the individual and concessions, should be instituted and these funds used to reconstruct abused sites. If this program is not feasible, it should be required that a seasonal ranger or naturalist accompany the larger groups during the heavy attendance periods. The National Park Service must become actively involved in preventative trail maintenance, involving those who most frequently use the trails.

National Park Concessions, Inc.

The major program of National Park Concessions should be to reduce its areal impact and transfer many of its activities out of the Chisos Basin. The complex is too large and critically located in the lower margin of the unstable evergreen woodland. The complex has greatly altered the natural drainage patterns, created extreme erosion sites, created many hard-surfaced and compacted areas, introduced numerous exotic and unnatural plant species, and made great demands on water and sewage facilities. The latter is presently creating the pollution problem at the Trailhead below the Ranger Station. Most of the facilities except for dining, food supplies, and automotive services could be more efficiently provided with less irreparable landscape damage at lower elevations in the park. Expansion of facilities and the trucking of supplies would be reduced, not to mention the aesthetic damage that the large, bare complex does by falsifying the integrity of the woodland vegetation.

If the reduction of lodging is not feasible, a vigorous program to revegetate the entire area must be initiated immediately to obscure the sprawl. To accompany the program, the woodland should be given total possession of its only natural invasion pathway into the Upper Basin. By removing the warehouse, roundhouse, paved road, and structures along the road, the ravine could be freed of most impact. All storage of supplies and housing of support personnel can certainly be done in less critically vegetated lower elevations. This program would also reduce large quantities of road runoff water and provide a more aesthetic and natural vegetation background for the existing complex. Every effort should be made to stabilize the abandoned area by the basic rehabilitation-revegetation program.

The areas presently impacted and those which are abandoned should be stabilized and revegetated according to the basic program. The exotic and introduced species program should also be conducted in the area.

Trails

The major program should be directed toward the phasing out of horse use on the trail system in the Chisos Basin if the long-term use of trails in planned. Because the trail system spans many miles of xerically adapted vegetation that can only slowly revegetate and stabilize the unstable slopes, the near-daily heavy use precludes little vegetation recovery to provide a natural access to the remote areas of the mountains. Few sections of the young trail system indicate stability to insure continued use in near-natural condition for years to come.

If an alteration in impact is not obtained, a long-range major program with great expenditures and consultation with ecologists, geologists, hydrologists, and engineers must be immediately instituted to insure stabilization, revegetation, and rehabilitative maintenance. A program to determine specific effects of the horse upon the trail and vegetation must be established, along with permanent plots for future comparative work. It is definitely certain that the present maintenance program is obsolete and of more detriment to the surrounding vegetation than no maintenance at all. The many days of trail-crew denuding and soil movement only promote the continued deterioration of the system which "nature" can do more naturally in several minutes during rainfall. The abandonment and rebuilding process does not provide a solution to the problem, as can be witnessed presently in the system. The few branches and fallen logs placed in the man-made gullies are not conducive to rehabilitation or revegetation.

New approaches to trail rehabilitation and maintenance should be instituted with increased crew personnel and equipment to support them. The research program must consider hard surfaces on the steep, unstable slopes of the Boot Canyon and Laguna Meadow trails and the incorporation of more drainbars. The use of drainbars to trap erosion products for maintenance purposes must be considered. This will require the use of small, powered soil conveyors since long distances must be covered and large quantities of soil and rocks must be transported in some regions of the trail system. Controlled plantings of grasses, shrubs, and trees incorporated into stone-covered slopes could reduce erosion, slippage, and shortcutting by trail riders and hikers. Immediate action must be taken to prevent horses from walking on the outer lip of the trail tread.

Since major concern has been focused on the destructive role of horses on the trail and vegetation, major consideration must be given to the cessation or reduction of horse use where it might increase use on a single trail section. Evidence indicates that the more mesic vegetation types, where stable, are less affected by trails than the more xeric vegetation types; however, more data is needed to substantiate such indications since long-range trends must be considered. A comparison of the vegetation along the lower, southern exposures on the Laguna Meadow Trail with that of its upper, northern exposures could supply pertinent data. The condition of the Window Trail and section of trail between Upper-Lower Basin, which are poor vegetationally as a result of impact, show evidence of increased or double use.

A policy directed toward reduced horse impact on Juniper Flat should be instituted. The vegetation recovery of Laguna Meadow and Stipa Flat indicates that the present condition of Juniper Flat is not natural or necessary. The flat, being close to the campground and available to less capable hikers, offers a unique habitat for an interpretative program, as does the vegetation along the short-cut trail to Laguna Meadow Trail. This trail should be restricted to hikers and have little preventative maintenance.

The complex trail system on the northern exposure of the slope between the Campfire Circle and the Ranger Station should be reduced to a single trail, as the present complex affects too great an area. The abandoned trails must undergo the basic rehabilitative-revegetation program and not receive the usual strategically positioned boulder and log.

Campground

The major rehabilitation program of the main campground and group campground areas is the control of visitors' walking while using the facilities provided. The aims should be to reduce erosion and compaction and to promote the development of a more natural vegetation. The entire campground, especially the present erosion sites and slopes, should undergo the basic rehabilitative-revegetation program. The introduction of trees and shrubs listed in the basic program is needed around the bare campsites and comfort stations to further the trend toward the potential evergreen woodland vegetation of the area.

To accompany the human control, erosion control, and revegetation programs, an attempt should be made to alleviate the habitats of the exotic and "weedy" species. The control of human walking and erosion will assist this significantly. The natural areas should be cleaned of camping debris and controlled by designated pathways wherever they must be traversed. The natural areas should also be ridded of the many *Cupressus arizonica* trees, and native trees, listed in the basic program, used to replace them.

Ranger Station

The major program of the Ranger Station and area should be the expansion of the facility into a Ranger Station and Mountain Woodland Interpretive Center. The center should occupy the present impacted circle and be a circular, two-storied building with Ranger offices and restrooms on the ground level and an overhanging second level consisting of a 360° observation floor, and with a centrally located, self-guided interpretive center. With the improvement or relocation of concession lodging to a lower elevation and with a vigorous revegetation program, the present impacted area would provide a picturesque view of the basin and would be an excellent educational asset to the Park. A circular parking arrangement around the base of the center would alleviate the present large parking lot, obscuring the automobiles from the viewers, and more appropriately provide for runoff in all directions. The included restroom facilities would permit the removal of the comfort station below the present Ranger Station, while the fire and rescue equipment could also be obscured from the visitors' view.

From the center, the visitor could be directed to a self-guided nature tour of the Window View circle, Juniper Flat-Laguna Me: 'ow Trail shortcut, or the longer Window Trail.

SCIENTIFIC AND COMMON NAMES OF PLANTS USED IN TEXT

Scientific name	Common name
Acacia biuncifera	
A. constricta	Mescat acacia
A. roemeriana	Roemer acacia
Acer grandidentatum	Bigtooth maple
Agave chisoensis	Chisos agave
A. lecheguilla	Lechuguilla
A. scabra	Agave
Aloysia lycioides	Whitebrush
A. Wrightii	Wright aloysia
Alternanthera peploides	Mat chaff-flower
Andropogon gerardi	Big bluestem
Anisacanthus insignis	Dwarf anisacanth
Aquilegia longissima	Longspur columbine
Aristida divaricata	Poverty threeawn
A. glauca	Blue threeawn
A. orcuttiana	Single threeawn
Artemesia ludoviciana	Louisiana sagewort
Atriplex canescens	Fourwing saltbush
Baccharis glutinosa	Seepwillow baccharis
Baileya multiradiata	Desert baileya
Boerhaavia coccinea	Scarlet spiderling
Bothriochloa barbinodis	Cane bluestem
Bouteloua breviseta	Chino grama
B. curtipendula	Sideoats grama
B. eriopoda	Black grama
B. gracilis	Blue grama
B. hirsuta	Hairy grama
Bouvardia ternifolia	Scarlet bouvardia
Bromus unioloides	Rescuegrass
Carya sp.	Hickory
Ceanothus greggii	Desert ceanothus
Celtis reticulata	Netleaf hackberry
Cenchrus incertus	Coast sandbur
Cercocarpus montanus	True mountainmahogany
Cheilanthes eatoni	Eaton lipfern
Chloris virgata	Showy chlosis
Chrysactinia mexicana	Damianita
Clematis drummondi	Texas virgins bower
Conyza canadensis	Horsetail conyza
Croton pottsii	Leatherweed croton
Cupressus arizonica	Arizona cypress
Cynodon dactylon	Bermudagrass
Dalea frutescens	Black dalea

Scientific name	Common name
Dasylirion	Sotol
D. leiophyllum	Smooth sotol
Digitaria californica	Arizona cottontop
Diospyrus texana	Texas persimmon
Echinochloa crusgalli	Barnyardgrass
Eragrostis barrelieri	Mediterranean lovegrass
E. intermedia	Plains lovegrass
Erioneuron grandiflorum	Large flowered tridens
E. pulchellum	Fluffgrass
Euphorbia strictospora	Slimseed euphorbia
Eysenhardtia texana	Texas kidneywood
Fouquieria splendens	Ocotillo
Fraxinus greggii	Gregg ash
Galium wrightii	Wright buttonweed
Garrya lindheimeri	Lindheimer silktassel
Glossopetalon spinescens	Spiny greasebush
Heteropogon contortus	Tanglehead
Hilaria mutica	Tobosa
Juniperus deppeana	Alligator juniper
J. flaccida	Drooping juniper
J. pinchoti	Redberry juniper
Larrea tridentata	Creosotebush
Leptochloa dubia	Green sprangletop
Lycurus phleoides	Wolftail
Machaeranthera pinnatifida	
Marrubium vulgare	Common horehound
Melampodium leucanthum	Plains blackfoot
Mimosa biuncifera	Catclaw mimosa
Muhlenbergia emersleyi	Bullgrass
M. porteri	Bush muhly
M. rigida	Purple muhly
Nolina	Nolina
N. erumpens	Foothill nolina
Opuntia	Pricklypear
O. engelmannii	Engelman pricklypear
O. kleiniae	Candle cholla
O. leptocaulis	Pencil cholla
Panicum hallii	Halls panicum
P. obtusum	Vine mesquite
Parthenium incanum	Mariola parthenium
Peganum harmala	Harmal peganum
Pellaea intermedia	Creeping cliffbrake
Perezia nana	Desertholly perezia
Phanerophlebia umbonata	
Pinus cembroides	Mexican pinyon
Piptochaetium fimbriatum	Pinyon-ricegrass

Scientific name	Common name
Polygala alba	White milkwort
P. scoparioides	Broom milkwort
Porophyllum scoparium	Poreleaf
Prosopis glandulosa	Honey mesquite
Pseudotsuga menziesii	Douglas fir
Quercus emoryi	Emory oak
Q. gravesii	Graves oak
Q. grisea	Gray oak
Q. intricata	Dwarf oak
Q. pungens	Sandpaper oak
Rhamnus betulaefolia	Birchleaf buckthorn
Rhus aromatica	Fragrant sumac
R. microphylla	Littleleaf sumac
R. virens	Evergreen sumac
Rivina humilis	Bloodberry
Salix sp.	Willow
Salsola kali	Russianthistle
Salvia regla	Mountain sage
Schizachyrium scoparium	Little bluestem
Senecio longilobus	Threadleaf groundsel
S. millelobatus	Manybract groundsel
Setaria macrostachya	Plains bristlegrass
Solanum elaeagnifolium	Silverleaf nightshade
Sorghum halpense	Johnsongrass
Sphaeralcea angustifolia	Narrowleaf globemallow
Sporobolus cryptandrus	Sand dropseed
Stipa sp.	Needlegrass
S. eminens	Southwestern needlegrass
S. tenuissima	Finestem needlegrass
Tamarix gallica	Saltcedar
T. pentandra	Tamarisk
Tribulus terrestris	Puncturevine
Trixis californica	American trixis
Vauquelina angustifolia	Slimleaf vanquelinia
Viguiera stenoloba	Skeleton goldeneye
Xanthocephalum	Broomweed
X. microcephalum	Threadleaf sagewort
X. sarothrae	Broom snakeweed
Ximenesia encelioides	Golden crownbeard
Yucca thompsoniana	Thompson yucca
Y. torreyi	Spanish dagger
Zexmenia brevifolia	Southern zexmenia

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